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American Society for Testing Materials

ORGANIZED IN 1898
INCORPORATED IN 1902

PROCEEDINGS, PART I

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

The following Summary records the action taken by the Society at the Annual Meeting on the Recommendations Affecting Standards and Tentative Standards appearing in the Annual Reports of the Standing Committees. In the individual committee reports attention is called through an editorial footnote to any modifications of the recommendations or where the recommendations of the committee were not approved. In all other instances it is to be understood that the recommendations were approved as submitted by the committee.

SUMMARY OF THE PROCEEDINGS OF THE THIRTY-EIGHTH ANNUAL MEETING

Detroit, Mich., June 24–28, 1935

The Thirty-eighth Annual Meeting of the American Society for Testing Materials was held at The Book-Cadillac, Detroit, Mich., June 24–28, 1935. The following is an analysis of the registered attendance at the meeting: Members in attendance or represented, 766; guests, 246; total, 1012; ladies, 124. The corresponding statistics for the Thirty-seventh Annual Meeting are as follows: Members in attendance or represented, 721; guests, 102; total, 823; ladies, 132.

The Third Exhibit of Testing Apparatus and Related Equipment sponsored by the Society was held in the Grand Ballroom of The Book-Cadillac throughout the five days of the annual meeting. In the 38 booths comprising the Exhibit there was displayed a wide range of commercial testing and research instruments, as well as apparatus being used for special investigational work. Twenty-two companies in the industry sponsored booths showing much new equipment as well as improvements in existing types of apparatus, and several research laboratories of universities, industrial companies, etc., displayed special equipment they had devised for research work.

Very interesting booth displays were arranged by six of the Society's committees functioning in the following fields: Corrosion of non-ferrous metals and alloys, die-cast metals and alloys, metallography, thermometers and laboratory glassware, petroleum products and lubricants, and electrical insulating materials. Each of these committees demonstrated various phases of its work, through the showing of test specimens used in corrosion tests, etc., or displaying apparatus which the committee has been responsible for developing and standardizing.

FIRST SESSION—TUESDAY, JUNE 25, 10 A. M.

Opening Session

Past-President F. O. Clements in the chair.

Past-President Clements in opening the Thirty-eighth Annual Meeting referred briefly to the outstanding features of this annual meeting which were of particular significance, mentioning specifically the exhibit of testing apparatus and related equipment, the symposium on roads and rides, the Marburg Lecture, the annual A.S.T.M. Dinner, and the symposium on spectrographic analysis. The chairman also referred briefly to the many activities which the Society has fostered through its standing committees during the past year as evidenced by the many reports to be presented at the technical sessions. On behalf of the Detroit Committee on Arrangements, Chairman Clements expressed the wish that it would be a most successful meeting.

The chairman then introduced Harvey J. Campbell, Jr., Secretary, Detroit Board of Commerce, who extended a very cordial welcome to the Society on the occasion of its first annual meeting in Detroit. He reviewed briefly the history of the city, the fourth largest in the United States and the center of the automobile industry. He called attention to the excellent geographical location of the city in the heart of the Great Lakes region and expressed the belief that the city was destined to continue to enjoy a place among the leading industrial and metropolitan cities of the world.

The chairman then presented C. F. Hirshfeld, Chief of Research Department, The Detroit Edison Co., who spoke on "Relation of Specifications to the Engineering Profession." Mr. Hirshfeld presented a very interesting paper[1] in which he pointed out that the practice of engineering is based upon the choice and use of materials adapted to produce the desired technical and economic results and accordingly a knowledge of their properties and characteristics is absolutely essential. He stated that it is not only necessary that the engineer shall have available in useable form this extensive information regarding materials but also that he shall be able to define or describe each one of them sufficiently accurately and specifically. Such description has come to be known as specification. The engineer must realize always that each item of a technical specification dealing with materials is of value only as it affects the usefulness of the material for a specific purpose.

Since the application of materials practically always precedes the knowledge required for technically and commercially satisfactory specifications, Mr. Hirshfeld expressed the belief that back of it all lies research and that in general we progress in proportion to the extent of the research. He presented a very characteristic picture of the way in which engineering, materials and specifications develop and showed that we progress only because we maintain a more or less precarious but nevertheless practical balance between the development of knowledge of the properties of materials, the application of such materials to engineering purposes and the production of useable specifications. Thus, successful specification is seen to be one of the prerequisites for the success of any engineering project, and the practice of engineering without specification is a practical impossibility.

The chairman then presented President Hermann von Schrenk who delivered the annual Presidential Address in which he pointed out two broad steps which he believes may increase the value and utility of A.S.T.M. work. Practically every meeting is featured by a symposium on one or more important engineering materials subjects—collections of papers by individual experts on a particular subject or material. Doctor von Schrenk would like to see this method of presenting valuable information and data to the engineer extended so that symposiums would not only bring together experts on different materials, but also more direct participation by standing committees of the Society. This would result in a closer tying together of results of diverse investigations. His second major point was, briefly, to have committees give, where feasible, information with respect to specifications concerning permissible and proper uses; in this way indicating to the user: first, what A.S.T.M. standards exist with reference to various kinds of uses, and second, reasons why certain A.S.T.M. specifications should be considered for the use of such material. "In other words a closer tying in of the various standards."

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[1] Published in A.S.T.M. *Bulletin*, July, 1935.

Chairman Clements then introduced the Secretary-Treasurer, C. L. Warwick, who presented the report of the Executive Committee. The report presented certain modifications in the Regulations Governing Standing Committees, and discussed membership, finances, publications, standing committee activities, district committees, Society and Regional Meetings, and inter-society and other cooperative relations.

The chairman then recognized J. M. Darke, chairman of the Committee of Tellers, who reported the results of the letter ballot on election of officers. Of the 719 ballots cast, the results were as follows:

For President, to serve for one year: H. S. Vassar, 717 votes.
For Vice-President, to serve for two years: A. E. White, 715 votes.
For Members of Executive Committee, to serve for two years:
    W. H. Graves, 714 votes.
    R. L. Hallett, 714 votes.
    N. L. Mochel, 713 votes.
    H. H. Morgan, 710 votes.
    W. R. Webster, 711 votes.

In accordance with the ballot the chair declared the officers listed above elected.

The chairman then introduced the newly elected members of the Executive Committee.

At the request of the chairman, Past-President K. G. Mackenzie and H. W. Gillett escorted the Vice-President-Elect, A. E. White, to the chair, who responded and expressed sincere appreciation of the honor of his election and of the opportunity to serve the Society in this capacity. Mr. White stated that he realized the office entailed responsibilities which he would make every effort to fulfill.

The chairman then requested Past-Presidents T. R. Lawson and K. G. Mackenzie to escort the President-Elect, H. S. Vassar, to the chair. Mr. Vassar in expressing sincere appreciation of the honor of his election to the Presidency made the following remarks:

> "In my association with the Society in some of its committee work, on the Executive Committee, and in attendance at these meetings, there are two things that impress me about the Society, two things in which I think it differs somewhat from any other technical or trade organizations. The first is in the great capacity for arduous work which is shown by many of the members of our standing committees, work which is non-spectacular but which is often tedious and which redounds very much to the glory of the Society rather than of the individual. The second thing I have noticed is the spirit of cooperation which marks the work of the Society. That is partly due perhaps to the general set-up of the Society which provides for the representation of what are often conflicting interests on the various standing committees. Most of our members, in the internal relationships of the Society as well as in our relationships with other societies, have shown a great willingness to go what is often called the second mile.

I believe that one of our outstanding characteristics, one of the things that has made this organization the success it has been through the years, has been that willingness to face facts on the part of these interests that are often conflicting. A leading electrical engineer once said: "Cooperation is not a sentiment, it is an economic necessity." It seems to me that if some of the spirit that has characterized this organization could be carried over today into the study and into the handling of some of the national questions that vex, annoy and irritate, a great deal would be accomplished towards their satisfactory settlement.

Just a word as to the year on which we are entering. The conventional thing to do is to ask for a continuance of your cooperation. I do not think that that is at all necessary, because I look forward personally to the new year with absolute confidence in the friendly spirit that has been shown in all the affairs of the Society, believing there will be a continuing upward trend through the united efforts of the individual members and the officers, each contributing and doing his appointed service."

The meeting then adjourned till 2 p. m.

SECOND SESSION—TUESDAY, JUNE 25, 2 P. M.

Testing; Yield Strength

President Hermann von Schrenk in the chair.

The report of Committee E-10 on Standards was presented from manuscript by the chairman, T. R. Lawson.

The report of Committee E-9 on Research was presented from manuscript by the chairman, P. H. Bates.

The report of Committee E-1 on Methods of Testing was presented by the chairman, W. H. Fulweiler. It was announced that the proposed revisions of the Standard Specifications for Round-Hole Screens for Testing Purposes (E 17 – 33), the Tentative Methods of Verification of Testing Machines (E 4 – 34 T) and the Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 32 T), which appeared in the report as information, would, if approved by letter ballot of the committee, be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "Measurement of Particle Size Distribution by Optical Methods," by R. N. Traxler and L. A. H. Baum, was presented by Mr. Traxler and discussed.

A paper entitled "The Relation Between the Tension Static and Dynamic Tests," by H. C. Mann, was presented from manuscript by the author and discussed.

A paper entitled "The Hardness Testing of Light Metals and Alloys," by R. L. Templin, was presented by the author and discussed.

A paper entitled "A New Method and Machine for Dynamic Hardness Testing," by W. M. Patterson, was presented by the author and discussed.

Past-President H. F. Moore then assumed the chair.

In introducing the Informal Discussion on the Significance of "Yield Strength" of Metals in Design and Specifications the chairman stated that experience in the determination of yield strength for various materials is accumulating and questions have arisen regarding its significance and its utilization in design of structures and as a requirement in purchase specifications. This informal discussion was accordingly arranged to provide opportunity for statements of such experience and questions, and for presentation of critical comment thereon.

The discussion was introduced by the following papers:

"Yield Strength from the Viewpoint of Ferrous Metals," by L. H. Fry.

"Yield Strength from the Viewpoint of Non-Ferrous Metals," by R. L. Templin.

"Yield Strength from the Viewpoint of the Testing Engineer," by H. H. Morgan.

"Yield Strength from the Viewpoint of the Design Engineer," by J. B. Kommers.

"Elastic Strength and the Relationship to Creep," by M. F. Sayre.

Following their presentation the papers were discussed.

The meeting then adjourned till 8 p. m.

THIRD SESSION—TUESDAY, JUNE 25, 8 P. M.

Symposium on the Place of Materials in Automobile Roads and Rides

President Hermann von Schrenk and Mr. T. A. Boyd co-chairmen.

In introducing the Symposium on the Place of Materials in Automobile Roads and Rides,[1] President von Schrenk stated that the subject to be discussed was of particular significance and particularly appropriate for presentation in the industrial city of Detroit since it is the home of the automobile and so closely affiliated with the rubber industry.

He called attention to the statement that "there is probably no single machine in which so many principles of physics find their application in so small a space as in the modern automobile." The same thing might equally well be said of the materials employed in constructing the automobile and the roads on which it runs. In order to treat in a systematic manner the part which these materials play in the road, the tire and the automobile this symposium was arranged under the auspices of the Detroit Program Committee. The contents of the papers are not intended primarily to advance the knowledge of the specialists in this field but to stimulate discussion of the problems relating to these materials and the further developments which appear to be desirable and which the future may reasonably hold.

The following papers comprising the symposium were then presented by their authors from manuscript:

"The Road," by John S. Worley.

"Tires and Their Place in Automotive Transportation," by K. D. Smith.

"The Car," by O. T. Kreusser.

Following their presentation the papers were discussed, the discussion being opened by the following on behalf of certain of the interested standing committees of the Society having jurisdiction over materials that enter into the construction of roads, tires and automobiles:

F. C. Lang, for Committee D-4 on Road and Paving Materials.

R. R. Litehiser, for Committee C-9 on Concrete and Concrete Aggregates.

Martin Castricum, for Committee D-13 on Textile Materials.

H. A. Depew, for Committee D-11 on Rubber Products.

H. H. Morgan, for Committee A-1 on Steel.

A. L. Clayden, for Committee D-2 on Petroleum Products and Lubricants.

The meeting then adjourned till the following morning.

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[1] Available as a separate publication, October, 1935.

FOURTH SESSION—WEDNESDAY, JUNE 26, 9.30 A. M.

Steel, Wrought Iron, Cast Iron

(Held Simultaneously with Fifth Session)

Mr. W. M. Barr in the chair.

The report of Committee A-2 on Wrought Iron was presented by the secretary, G. H. Woodroffe. The proposed Tentative Specifications for Uncoated Wrought-Iron Sheets, and for Zinc-Coated (Galvanized) Wrought-Iron Sheets were accepted for publication as tentative. The proposed revisions of the Tentative Specifications for Wrought-Iron Plates (A 42 – 34 T) and for Wrought-Iron Rivets and Rivet Rounds (A 152 – 33 T) were accepted, the specifications as revised being continued as tentative.

The proposed revisions of the Standard Specifications for Common Iron Bars (A 85 – 27), for Refined Wrought-Iron Bars (A 41 – 30), for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 30), for Hollow Rolled Staybolt Iron (A 86 – 30) and for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34) were accepted for publication as tentative. The proposed revision of the Standard Specifications for Staybolt, Engine-Bolt and Other High-Grade Wrought-Iron Bars (A 84 – 33) was accepted for publication as tentative, with the following additional tentative revision of Section 7 (*a*), presented on the floor at the annual meeting, subject to favorable letter ballot of Committee A-2:[1]

Section 7 (*a*).—Change to read as follows by the addition of the italicized words and the omission of the words and figures in brackets:

> 7. (*a*) Grade A.—For bars ⅞ in. in diameter *or under*, a reduction in the minimum elongation in 8 in. specified in Section 6 (*a*) shall be permitted, but in no case shall the elongation be less than 28 per cent. [For bars ¾ in. or under in diameter, the elongation shall not be less than 25 per cent.]

The tentative revision of the Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 30) was approved for reference to letter ballot of the Society for adoption as standard.

The report of Committee A-6 on Magnetic Properties was presented by the chair. The proposed revisions of the Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 34) in the form of separate tentative definitions, and of the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 33) were accepted for publication as tentative.

The report of Committee A-1 on Steel was presented by the staff assistant, R. J. Painter. The proposed Tentative Specifications for Axle-Steel Concrete Reinforcement Bars and for Seamless Low-Carbon-Steel Still Tubes for Refinery Service were accepted for publication as tentative. The proposed revisions of the Standard Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 30), for Quenched High-Carbon-Steel Splice Bars (A 49 – 21), for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A 68 – 27), for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34), for Commercial Quality Hot-Rolled Bar Steels (A 107 – 33) and for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting

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[1] The proposed revision was submitted to letter ballot of Committee A-2 which consists of 55 members; 45 members returned their ballots, of whom 44 voted affirmatively and 1 negatively.

(A 108 – 33) were accepted for publication as tentative. The proposed revision of the Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 34 T) was accepted, the specifications as revised being continued as tentative.

The Tentative Specifications for Heat-Treated Steel Elliptical Springs (A 147 – 33 T) were approved for reference to letter ballot of the Society for adoption as standard. The tentative revisions of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 33) and for Rail-Steel Concrete Reinforcement Bars (A 16 – 33) were approved for reference to letter ballot of the Society for adoption as standard. The withdrawal of the Tentative Specifications for Carbon-Steel Castings for Industrial, Railroad and Marine Uses (A 154 – 33 T) was approved. The List of Specifications for Steel Suitable for Fusion Welding (A 151 – 33), with proposed additions, was approved for reference to letter ballot of the Society for publication in the 1935 Supplement to Book of A.S.T.M. Standards.

It was announced that the Proposed Specifications for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F., which appeared in the preprinted report as information, would, if approved by letter ballot of the committee, be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting. It was also announced that the committee had completed for submission to Committee E-10 for publication as tentative new Specifications for Carbon-Steel Heat Exchanger and Condenser Tubes, for Electric-Resistance Welded Steel, and Open-Hearth Iron Boiler Tubes, for Carbon-Steel and Alloy-Steel Castings for Railroads, for Carbon-Steel Castings for Miscellaneous Industrial Uses, for Forged Steel Pipe Flanges, and for Nut Material Used in Bolting for High Pressure and/or High Temperature from Room Temperature to 1100 F. Revisions in three existing tentative specifications are also expected to be presented to Committee E-10 covering high tensile strength carbon steel plates and cold-rolled strip steel. Tentative revisions will also be presented in the existing Standard Specifications for Steel for Buildings (A 9 – 34), for Steel for Bridges (A 7 – 34), for Structural Silicon Steel (A 94 – 33), for Quenched Carbon-Steel Track Bolts (A 50 – 33), for Quenched Alloy-Steel Track Bolts (A 51 – 33), for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34), for Boiler and Firebox Steel for Stationary Service (A 70 – 33), and several specifications covering Steel for High-Temperature Service.

A paper entitled "The Effect of Cold Bending on the Elastic Properties of Heavy (3½ in. Thick) Steel Plates," by C. H. Gibbons, was presented from manuscript by the author and discussed.

The report of Committee A-3 on Cast Iron was presented by the chairman, Hyman Bornstein. The proposed Tentative Specifications for Automotive Gray-Iron Castings were accepted for publication as tentative. The proposed revision of the Tentative Specifications for Gray-Iron Castings (A 48 – 32 T) and for Cast-Iron Culvert Pipe (A 142 – 34 T) were accepted, the specifications as revised being continued as tentative. The proposed revision of the Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 30 T), which appeared in the report as preprinted, was withdrawn by the committee for further consideration.

A paper entitled "Rear Axle Gears: Factors Which Influence Their Life," by J. O. Almen and A. L. Boegehold, was presented jointly by the authors and discussed.

The meeting then adjourned till 2 p. m.

FIFTH SESSION—WEDNESDAY, JUNE 26, 9.30 A. M.

Paint, Timber, Naval Stores

(Held Simultaneously with Fourth Session)

Vice-President H. S. Vassar in the chair.

The report of Committee D-1 on Preservative Coatings for Structural Materials was presented by the chairman, Allen Rogers, who called on the secretary, M. Rea Paul, to give the detailed recommendations of the committee. The proposed Tentative Specifications for White Pine Wood to Be Used in Weather Tests of Paints with certain editorial changes presented on the floor at the annual meeting, specifications for Blue Lead (Basic Sulfate), and Methods of Test for Comparative Hiding Power of White Pigments and of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number) were accepted for publication as tentative.

The immediate adoption as standard of the proposed revision in the Standard Specifications for Dry Bleached Shellac (D 207 – 33) and for Shellac Varnish (D 359 – 34) was unanimously approved for reference to letter ballot of the Society, this recommendation requiring a nine-tenths vote.

The proposed revisions of the Standard Specifications for Raw Tung Oil (D 12 – 33), and Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 – 27) and of White Linseed Oil Paints (D 215 – 29) were accepted for publication as tentative.

The proposed revisions of the Tentative Methods of Test for Tinting Strength of White Pigments or White Pigment Pastes (D 332 – 34 T), for Mass Color and Tinting Strength of Dry Color Pigments or Pastes (D 387 – 34 T) and for Soluble Nitrocellulose Base Solutions (D 365 – 33 T) were accepted, the methods as revised being continued as tentative.

The Tentative Specifications for Titanium Barium Pigment (D 382 – 34 T), for Titanium Calcium Pigment (D 383 – 34 T) and for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (95 to 96 per cent Grade) (D 343 – 32 T) were approved for reference to letter ballot of the Society for adoption as standard. The adoption as standard of the Tentative Specifications for Ethylene Glycol Mono Butyl Ether (D 330 – 32 T) and for Ethylene Glycol Mono Ethyl Ether (D 331 – 32 T), proposed on the floor at the annual meeting, was unanimously approved for reference to letter ballot of the Society, subject to favorable letter ballot of Committee D-1.[1]

The tentative revisions of the Standard Methods of Routine Analysis of Dry Red Lead (D 49 – 33), of White Linseed Oil Paints (D 215 – 29) and of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 – 27) were approved for reference to letter ballot of the Society for adoption as standard.

The withdrawal of the Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (90 to 91 per cent Grade) (D 342 – 32 T), proposed on the floor at the annual meeting, was unanimously approved, subject to favorable letter ballot of Committee D-1.[2]

It was announced that the committee had completed the preparation of Specifications for Southern Yellow Pine Wood to be Used in Weather Tests of Paints which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

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[1] This recommendation was submitted to letter ballot of Committee D-1 which consists of 182 members; 68 members returned their ballots, of whom 46 voted affirmatively and none negatively.

[2] This recommendation was submitted to letter ballot of Committee D-1 which consists of 182 members; 68 members returned their ballots, of whom 42 voted affirmatively and none negatively.

The report of Committee D-10 on Shipping Containers was presented by the Assistant Secretary. The withdrawal of the Tentative Specifications for Wooden Boxes, Nailed and Lock-Corner Construction, for the Shipment of Canned Foods (D 44 - 20 T), for Canned Foods Boxes, Wirebound Construction (D 45 - 17 T), General Specifications for Wooden Boxes, Nailed and Lock-Corner Construction (D 68 - 22 T) and for 4-One Boxes and Similar Type Boxes (D 118 - 21 T) was approved.

The report of Committee D-7 on Timber was presented by the chairman, Hermann von Schrenk. In presenting the report Mr. von Schrenk called upon S. R. Church to present the report of Subcommittee VI on Timber Preservatives. The Tentative Specifications for Creosote (D 390 - 34 T) and for Creosote Coal-Tar Solution (D 391 - 34 T) were approved for reference to letter ballot of the Society for adoption as standard. The proposed revision of the Tentative Specifications for Timber Piles (D 25 - 30 T) was accepted, the specifications as revised being continued as tentative. The proposed revision of the Standard Specifications for Structural Wood Joist and Planks, Beams and Stringers, and Posts and Timbers (D 245 - 33) was accepted for publication as information.

A paper entitled "The Distribution and Variations of Certain Strength and Elastic Properties of Clear Southern Yellow Pine Wood," by A. W. Brust and E. E. Berkley, was presented from manuscript by Mr. Brust.

A paper entitled "Methods of Testing Fire-Retardant Treated Wood," by C. R. Brown, was presented from manuscript by the author and discussed.

The meeting then adjourned till 2 p. m.

SIXTH SESSION—WEDNESDAY, JUNE 26, 2 P. M.

Rubber, Petroleum Products

Mr. E. W. Upham in the chair.

The report of Committee D-11 on Rubber Products was presented by the chairman, H. A. Depew. The proposed Tentative Methods of Physical Testing of Rubber Products (General Requirements), to supersede the present Standard Methods of Physical Testing of Rubber Products (D 15 - 32), and Methods of Tension Testing of Vulcanized Rubber, and Test for Adhesion of Vulcanized Rubber (Friction Tests) were accepted for publication as tentative. The immediate adoption as standard of the proposed revision of the Standard Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 - 34) was unanimously approved for reference to letter ballot of the Society, this recommendation requiring a nine-tenths vote.

The proposed revisions of the Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 - 34 T), for Insulated Wire and Cable: Performance Rubber Compound (D 353 - 34 T), Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 - 34 T) and for Rubber Insulating Tape (D 119 - 34 T) were accepted, the specifications as revised being continued as tentative. The withdrawal of the Standard Methods of Physical Testing of Rubber Products (D 15 - 32) was approved.

It was announced that the committee had completed the preparation of certain new methods including tests for aging of vulcanized rubber, adhesion of rubber to metal and flexing of rubber products which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee D-2 on Petroleum Products and Lubricants was presented by the chairman, T. A. Boyd. The editorial changes in the Standard Method of Test for Cloud and Pour Points (D 97 – 34) were accepted. The proposed revisions of the Standard Methods of Test for Distillation of Crude Petroleum (D 285 – 33), for Flash Point by Means of the Pensky-Martens Closed Tester (D 93 – 22) and for Saponification Number (D 94 – 28) were accepted for publication as tentative. The proposed revision of the Standard Method of Test for Flash Point of Volatile Flammable Liquids (Tag Closed Tester) (D 56 – 21) in the form of a separate Tentative Method of Test for Flash Point by Means of the Tag Closed Tester was accepted for publication as tentative.

The proposed revision of the Standard Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 – 33) in the form of a separate Tentative Method of Test for Viscosity by Means of the Saybolt Viscosimeter was accepted for publication as tentative with the following additional modifications, presented on the floor at the annual meeting, subject to favorable letter ballot of Committee D-2:[1]

Section 2 (*a*).—Make the following changes in Note 1 of this section:

Transfer and reletter Paragraph (*c*) as (*a*) and change "standard oil" to read "oil standard."

Reletter Paragraph (*a*) as (*b*) and add the following phrase: "subsequent to January 1, 1935."

Reletter Paragraph (*b*) as (*c*) and add the following: "provided the tube shows no evidence of damage or injury since certification."

In Note 2 change "standard oils" to read "oil standards."

Section 2 (*b*).—Change to read as follows by the addition of the italicized words and the omission of the words and figures in brackets:

[For referee testing the bath liquid shall be water. In tests at 210 F. (98.9 C.) the water bath may be heated by the direct injection of steam near the bottom of the bath.] The bath temperature necessary to maintain thermal equilibrium (while the oil in the oil tube is well stirred by the oil-tube thermometer) shall be within ±0.1 F. (0.06 C.) of the standard temperatures of 70 F. (21.1 C.) or 77 F. (25 C.) or shall not exceed 100.25, 122.35, 130.5, 141.0, 181.5 or 212.0 F. (37.9, 50.2, 54.7, 60.6, 83.1 or 100.0 C.), respectively, for the standard temperatures mentioned in Section 3. [For routine testing other bath liquids may be used (Note).] The level of the bath liquid shall not be lower than ¼ in. (0.5 cm.) above the overflow rim of the oil tube. *For referee testing the bath liquid must be one which in the bath used will meet the preceding bath-temperature conditions* (*Note*).

Change the note following Section 2 (*b*) from the form as preprinted to read as follows:

NOTE.—These temperature requirements can be met with water, aqueous solutions, and some baths with oil. In routine testing oil is generally used as the bath medium. This is allowable provided the temperature of the oil bath is adjusted so that the necessary condition of thermal equilibrium is maintained. It may be necessary to maintain the oil bath at slightly higher temperatures than those specified in the preceding paragraph. Temperature differentials between oil bath and oil tube necessary to maintain thermal equilibrium may be double those given above.

Section 2 (*d*).—In the requirements for the stem of the thermometer delete in the third sentence the word "preferably" from the phrase "The stem shall preferably be made with an enlargement . . . . ."

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[1] The proposed revision was submitted to letter ballot of Committee D-2 which consists of 87 members; 57 members returned their ballots, of whom 53 voted affirmatively and none negatively.

Section 4 (d).—Change the first two sentences of this section from the form as printed, namely,

> The oil to be tested shall be heated to not more than 3 F. (1.7 C.) above the temperature of test. If the test temperature is below room temperature the oil shall be cooled to not more than 3 F. (1.7 C.) below the temperature of test.

to read as follows:

> If the test temperature is above that of the room, the oil shall be heated to not more than 3 F. (1.7 C.) above the temperature of test and if the temperature is below that of the room the oil shall be cooled to not more than 3 F. (1.7 C.) below the temperature of test.
>
> In the last sentence of Section 4 (*d*) change the phrase "the bath temperature" to read "the indicated bath temperature."

Section 4 (e).—Change "overflow cup" to read "gallery."

Section 5.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> The time in seconds *as determined by the prescribed procedure*, with *the* proper calibration correction, [for the delivery of 60 ml. of oil] is the Saybolt Universal (or Saybolt Furol) viscosity of the oil at the temperature at which the test is made. Results shall be reported to the nearest 0.1 sec. for viscosity values below [500] *200* sec. and to the nearest whole second for values [500] *200* sec. or above.

Section 6.—Delete the word "duplicate" from the phrase "duplicate results in different laboratories . . . . ."

The tentative revisions of the Standard Methods of Test for Dilution of Crankcase Oils (D 322 – 33), for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 – 30), for Precipitation Number of Lubricating Oils (D 91 – 33) and for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 30) were approved for reference to letter ballot of the Society for adoption as standard.

The Proposed Method of Test for Oxidation Number of Lubricating Oils by the Sligh Method was accepted for publication as information.

The Diesel-Fuel-Oil Classification, with revisions presented on the floor at the annual meeting, was accepted for publication in the report as information subject to favorable letter ballot of Committee D-2.[1]

It was announced that the committee had completed the preparation of a proposed Tentative Method of Test for Vapor Pressure of Motor and Aviation Gasoline, and revisions of the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 33) and of the Tentative Definitions of Terms Relating to Petroleum (D 288 – 31 T) which, if approved by letter ballot of the committee, would be presented to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "The Effect of Volatility on Oil Consumption," by L. L. Davis and R. D. Best, was presented by Mr. Davis and discussed.

A paper entitled "The Influence of Engine Design on Oil Consumption," by M. O. Teetor, was presented by the author and discussed.

The meeting then adjourned till 4 p. m.

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[1] The proposed revised classification was submitted to letter ballot of Committee D-2 which consists of 87 members; 56 members returned their ballots, of whom 47 voted affirmatively and none negatively.

WEDNESDAY, JUNE 26, 2 P. M.

Round-Table Discussion on Ductility Testing of Sheet Metals

A Round-Table Discussion on Ductility Testing of Sheet Metals was held under the auspices of the Section on Testing Thin Sheet Metals in cooperation with the Section on Bend Tests for Ductility of the A.S.T.M. Committee E-1 on Methods of Testing. In opening the meeting the co-chairmen, A. L. Davis and A. B. Kinzel, reviewed briefly the activities of the committee, and the objects in arranging this round-table meeting for the purpose of furthering knowledge covering the use of bend, cupping or other methods of testing the ductility or drawing properties of sheet metals. The discussion was then opened by the presentation of papers by C. L. Eksergian, H. T. Morton and C. H. Davis, which were followed by general discussion and mutual exchange of information on the subject.

SEVENTH SESSION—WEDNESDAY, JUNE 26, 4 P. M.

Edgar Marburg Lecture

President Hermann von Schrenk in the chair.

President von Schrenk in opening the session devoted to the Edgar Marburg Lecture briefly explained that this annual memorial Lecture was established ten years ago as a means of honoring and perpetuating the memory of the first Secretary-Treasurer of the Society, Edgar Marburg. In addition to thus commemorating one who contributed so much to the Society during the years of its early development it brings to the membership valuable expositions on outstanding developments in the materials engineering field by authorities in the sciences and engineering.

The President then introduced the tenth Edgar Marburg Lecturer, Dr. L. B. Tuckerman, Principal Scientist, and Assistant Chief, Division of Mechanics and Sound, National Bureau of Standards, who presented a very interesting lecture on "Aircraft: Materials and Testing." Doctor Tuckerman pointed out that all fields of science and technology have contributed to the development of the modern airplane. The lecturer showed that the major structural problem in aircraft is light-weight construction of an entirely different order of lightness than had been necessary previously. Success in meeting this demand has come from a combination of empirical design with theoretical investigations and materials and structural tests of a volume unprecedented in the history of any comparable structural field.

Theoretical and experimental investigations all show that the securing of light-weight construction depends upon spreading the material as far as possible out from the axis of the structure or its structural elements. Typical light-weight construction is therefore secured by thin-walled construction. The limit of the spreading is set by local instabilities: wrinkling, twisting, crumpling or other types of collapse, of the thin material. The problem is to secure the best possible balance between plastic yielding depending upon the strength-density ratio of the material, and major or local instabilities dependent upon its modulus density ratio and finally the transitions between them dependent upon an accurate knowledge of its stress-strain curve. These conclusions were illustrated by examples of simple structural members used in aircraft.

Comparison made of the significant properties, density, strength-density ratio, and modulus-density ratio of selected materials show that from these purely structural considerations, with the materials now available, there is little choice between the three types of construction now in use, wood, light aluminum alloys, and high-strength alloy steels.

The choice between them must be based on other considerations, ease of fabrication, resistance to deterioration by weathering, etc., and finally upon knowledge of the designs which will utilize best the possibilities of the material.

With the best designs so far produced it is possible to make full use of the strength of materials already available only in relatively small parts of the structure. The modulus-density ratio is still the limiting property of the material and this ratio is practically unaltered by any treatment which can be given a material. Consequently no radical improvement in light-weight construction is at present to be expected from still further increasing the strength of the materials.

The lecturer stated that there is much room for improvement in the knowledge of designing to utilize more fully the strength of materials now available. Systematic series of tests on typical structural elements, covering ranges of materials, over-all dimensions, wall thickness and types of loading, sufficiently wide to determine all the types of instability and plastic yielding likely to occur in practical designs, to determine the limiting conditions of each type and their relations to the stress-strain properties of the material as determined by parallel coupon tests. Systematic tests such as these offer promise of materially improved light-weight construction.

He also pointed out that the principles, materials, and technique of light-weight construction developed chiefly in connection with aircraft are being increasingly used in other fields of construction, notably in light-weight railroad trains.

President von Schrenk in expressing appreciation to Doctor Tuckerman for his fine exposition on the science of aircraft construction, a subject of particular interest to the A.S.T.M., presented to him on behalf of the Society the Edgar Marburg Lecture Certificate.

The meeting then adjourned till 7 p. m.

WEDNESDAY, JUNE 26, 7 P. M.

Annual Meeting Dinner

Chairman, President von Schrenk.

Toastmaster, Mr. C. F. Kettering.

President von Schrenk introduced J. R. Freeman, Jr., chairman of the Committee on Award of the Charles B. Dudley Medal, who presented as the recipients of the 1935 Award of the Dudley Medal, Messrs. C. A. Hogentogler and E. A. Willis for a paper under their joint authorship entitled "Subgrade Soil Testing Methods," presented at the 1934 annual meeting of the Society. Mr. Freeman explained that the Medal is awarded annually by the Society to the author or authors of a technical paper considered of outstanding merit and an original contribution on research in engineering materials. He stated that the committee recognized that the paper presented by Messrs. Hogentogler and Willis represented an unusually careful study of broad scope of certain fundamental properties of soils and eminently merits the recognition conveyed by the Dudley Medal Award.

On behalf of and as the representative of the Society, President von Schrenk then made the Ninth Award of the Charles B. Dudley Medal to Messrs. Hogentogler and Willis.

In accepting the Medal on behalf of Mr. Willis and himself, Mr. Hogentogler stated that they greatly appreciated with sincere gratitude the recognition accorded by the Award of the Dudley Medal, and in accepting the Medal with due appreciation of the honor which accompanies it they wished to acknowledge the fact that the work which merited the award was made possible only because of the cooperation of their assistants, their colleagues and their superiors. He stated that the tradition of worthy and painstaking research accomplished by the Department of Agriculture formed both an incentive and a substantial background for their studies of soil testing.

President von Schrenk then presented the Toastmaster, C. F. Kettering.

The Toastmaster introduced G. R. Thompson, Budget Director of Michigan, who was the official representative of Governor Fitzgerald. On behalf of His Excellency, Governor Fitzgerald, Mr. Thompson conveyed to the Society a most cordial welcome to Michigan and said that the Governor regretted exceedingly his inability to be present. The Governor sent his heartiest wishes for a most successful meeting.

The Toastmaster stated that the remainder of the program which was devoted to a consideration of "The Relationship of Materials to the House of Today and Tomorrow," was arranged for the purpose of giving a general picture of problems and progress, particularly from the materials viewpoint, in the important field of housing. This was a particularly timely subject in view of the current interest being shown both in this country and abroad. He pointed out that the quest today is for a house that is better and that costs less to build. In the effort to reach this difficult objective, there is much careful scrutiny of the design of houses, of the materials available of which to construct them, and of the various possible methods of constructing them in the factory and on location.

The Toastmaster then introduced M. L. Colean, Director, Low-Cost Housing and Technical Divisions, Federal Housing Administration, who presented a paper on "The Federal Housing Problem."[1] Mr. Colean discussed the policy of the Federal Housing Administration with respect to the house itself, rather than the financial aspects of the mortgage problem. He said that the endeavor to produce an adequate supply of dwellings should have a three-fold purpose: namely, to build better houses, to build more houses, and to provide the means for removing and replacing houses that have outlasted a reasonable usefulness. He indicated that better housing will come from several sources—a more rational and economical use of land, a more scientific planning, and more efficient use of better materials. He stated that the Federal Housing Administration is trying to cooperate with this movement to attain new and better materials and new methods of construction and is ready to accept the evidence of adequate tests. Industry, the technical professions and the Government are now alert to the necessities and opportunities inherent in the housing problem and these three elements should cooperate in a mutual endeavor to achieve a speedy and thorough solution of the problems. By maintaining such a cooperative effort we should soon be able to foresee a period in which home building will take its proper place among the major industries and the possibility of adequate housing be within the reach of the great majority of the American people.

The Toastmaster then introduced J. E. Burchard, Vice-President, Bemis Industries, Inc., who presented a paper on "The Role of Materials in Modern Housing."[2] Mr. Burchard called attention to the fact that there are two counter forces at work in the field of housing today. The one, that of the social reformer, recognizes many valid objections to the thesis of the single-family detached house as the ideal for all Americans, objections both economic and social. The other, the school of the prefabricator, accepts the ideal of the owned house but admits that houses must be much cheaper. Both strive to avoid the consequences, physiological and criminal, of the slum.

He indicated that prefabrication in itself will not alone, even if successful, take us out of the depression. He stated that ideal materials for prefabrication should be characterized by lightness, adequate structural strength, relative permanency of dimension, durability, reasonable resistance to shock, good resistance to heat transmission, good resistance to sound transfer, fire resistance, low cost, and beauty.

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[1] Extensively abstracted in A.S.T.M. *Bulletin*, October, 1935.
[2] Available as a separate publication, October, 1935.

He finds in the new plywoods the rehabilitation of wood as probably the most promising material for the prefabricating industry. He is not enthusiastic as to the use of precast and poured-in-place concrete but finds in the mosaic concrete of Earley and in asbestos-cement sheets as used by McLaughlin's American Houses the probable use of concrete in future for housing (other than foundations) as prefabricated, relatively thin, large sheets of considerable beauty for sheathing and finishing purposes. Mr. Burchard proclaimed the increasing development and use of other metals, notably aluminum and copper, relative to steel; he is not impressed by the employment of metal in frame or panel structure and suggested that the role of metals will be vastly increased as interior or exterior finish elements, but not as structure for the house.

He also predicted the virtual demise of brick and stone except in the homes of the wealthy and finds in glass the most romantic and fruitful of materials for the future. He stated, too, that fireproofness is desirable but not an essential quality. These statements by Mr. Burchard were made in connection with detached modern housing, whether prefabricated or not, as he expressly limited his talk by pointing out that community housing in any form becomes a large building operation.

The meeting then adjourned till the following morning.

EIGHTH SESSION—THURSDAY, JUNE 27, 9.30 A. M.

Corrosion

(Held Simultaneously with Ninth Session)

Mr. A. E. White in the chair.

The report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys was presented by the chairman, Jerome Strauss. The proposed Tentative Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate), for 12 per cent Chromium Steel Castings, for 19 per cent Chromium Steel Castings, and for 28 per cent Chromium Steel Castings were accepted for publication as tentative with certain editorial changes presented on the floor at the annual meeting.

It was announced that the committee had completed the preparation of specifications for chromium steel in sheet, plate and strip form, specifications for chromium-nickel steel in sheet and strip form, and six specifications for different types of chromium-nickel steel castings which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

The report of Committee A-5 on Corrosion of Iron and Steel was presented by the vice-chairman, F. N. Speller. The proposed Tentative Specifications for Electrodeposited Coatings of Zinc on Steel, for Electrodeposited Coatings of Cadmium on Steel, and for Electrodeposited Coatings of Nickel and Chromium on Steel were accepted for publication as tentative. The editorial changes in the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 30) and for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 30) were accepted. The Tentative Recommended Practice for Safeguarding Against Embrittlement of Hot-Galvanized Structural Steel Products and Procedure for Detecting Embrittlement (A 143 – 32 T) was approved for reference to letter ballot of the Society for adoption. The withdrawal of the Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 30) and of the Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 32 T) and for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 32 T) was approved.

A progress report of the Sectional Committee on Specifications for Zinc Coating of Iron and Steel was presented by the chairman, J. A. Capp, announcing the approval of certain standards for submission to the American Standards Association and discussing the possible reorganization of the committee.

A paper entitled "Continuous-Flow Corrosion Tests of Steel Pipe," by H. S. Rawdon and L. J. Waldron, was presented by Mr. Rawdon and discussed.

The report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys was presented by the chairman, T. S. Fuller, who called attention to several important changes in the report as preprinted. In presenting the report Mr. Fuller called upon W. H. Finkeldey to describe the work of Subcommittee VI on Atmospheric Corrosion of Non-Ferrous Metals and Alloys, on A. J. Phillips to present the report of Subcommittee VII on Corrosion in Liquids, and on C. L. Hippensteel to describe the work of Subcommittee VIII on Galvanic and Electrolytic Corrosion.

Mr. C. L. Hippensteel then assumed the chair.

The report of Committee D-14 on Screen Wire Cloth was presented by the secretary *pro tem*, J. R. Freeman, Jr., and was accepted for publication subject to approval by letter ballot of Committee D-14.[1] In presenting the report, Mr. Freeman called upon H. S. Rawdon to present a paper appended to the report entitled "Atmospheric Exposure Tests on Non-Ferrous Screen Wire Cloth," by G. W. Quick.

A paper entitled "Corrosion Testing Methods," by H. E. Searle and F. L. LaQue, was presented by Mr. LaQue.

A paper entitled "The Control of Corrosion in Air-Conditioning Equipment by Chemical Methods," by C. M. Sterne, was presented by the author and discussed.

The report of Committee D-19 on Water for Industrial Uses was presented by the vice-chairman, F. N. Speller.

The meeting then adjourned till 8 p. m.

NINTH SESSION—THURSDAY, JUNE 27, 9.30 A. M.

Coal, Textile Materials, Electrical Insulating Materials

(Held Simultaneously with Eighth Session)

Vice-President A. C. Fieldner in the chair.

Mr. Fieldner called on Vice-President H. S. Vassar to take the chair during the presentation of the reports of the two committees of which he is chairman.

The report of the Sectional Committee on Classification of Coals was presented by the chairman, A. C. Fieldner. The proposed revision of the Tentative Specifications for Classification of Coals by Rank (D 388 – 34 T) was accepted, the specifications as revised being continued as tentative.

The report of Committee D-5 on Coal and Coke was presented by the chairman, A. C. Fieldner. The proposed Tentative Definitions of the Terms Gross Calorific Value and Net Calorific Value of Fuels, and the Methods of Test for Grindability of Coal by Ball-Mill Method, for Grindability of Coal by Hardgrove-Machine Method, and for Screen Analysis of Coal were accepted for publication as tentative. The Tentative Method of Sampling Coke for Analysis (D 346 – 33 T), as revised, was approved for reference to letter ballot of the Society for adoption as standard.

A paper entitled "A Furnace for the Measurement of Coal-Ash Softening Temperature," by Elliott P. Barrett, was presented by the author and discussed.

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[1] The report was submitted to letter ballot of Committee D-14 which consists of 14 members; 10 members returned their ballots, of whom 9 voted affirmatively and none negatively.

The report of Committee D-13 on Textile Materials was presented by the chairman, H. J. Ball. The proposed Tentative General Methods of Test for Properties of Cotton Fibers, and Methods of Test for Shrinkage in Laundering of Silk and Rayon Woven Broad Goods, and for Strength of Rayon Woven Fabric when Wet were accepted for publication as tentative. The proposed revisions of the Tentative Methods of Estimating Hard Scoured Wool in Wool in the Grease (D 232 - 34 T), for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (D 276 - 33 T), Definitions and Terms Relating to Textile Materials (D 123 - 34 T), and Specifications for Tolerances and Test Methods for Rayon (D 258 - 32 T), for Tubular Sleeving and Braids (D 354 - 32 T), for Woolen Yarns (D 403 - 34 T) and for Worsted Yarns (D 404 - 34 T) were accepted, the tentative standards as revised being continued as tentative.

The proposed revisions of the Standard General Methods of Testing Woven Textile Fabrics (D 39 - 34), for Tolerances and Test Methods for Tire Cord, Woven and on Cones (D 179 - 33), for Hose Ducks and Belt Ducks (D 181 - 34) and for Cotton Sewing Threads (D 204 - 33) and Specifications for Textile Testing Machines (D 76 - 33), the latter in the form of separate tentative specifications, were accepted for publication as tentative. The Tentative Specifications for Holland Cloth (D 376 - 34 T) were approved for reference to letter ballot of the Society for adoption as standard.

It was announced that the committee had completed the preparation of Methods of Test for Fastness of Dyed or Printed Cotton to Laundering or Domestic Washing, for Slippage in Silk and Rayon Woven Broad Goods, for Fineness of Wool and for Testing Pile Floor Covering; also revisions in the existing Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 - 34 T) and for Worsted Yarns (D 404 - 34 T) which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "Testing of the Physical and Chemical Properties of Wool by Means of the Microscope," by Werner von Bergen, was presented from manuscript by the author.

The report of Committee D-9 on Electrical Insulating Materials was presented by the chairman, T. S. Taylor. The proposed Tentative Methods of Testing Shellac Used for Electrical Insulation were accepted for publication as tentative. The editorial changes in the Standard Methods of Testing Electrical Porcelain (D 116 - 34) were accepted. The proposed revision of the Standard Methods of Testing Electrical Insulating Oils (D 117 - 33) was accepted for publication as tentative.

The editorial changes in the Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T), Pasted Mica Used in Electrical Insulation (D 352 - 32 T) and Specifications for Black Bias-Cut Varnished Cloth Tape Used for Electrical Insulation (D 373 - 34 T) were accepted.

The proposed revisions of the Tentative Methods of Testing Varnishes Used for Electrical Insulation (D 115 - 34 T), Electrical Insulating Materials for Power Factor and Dielectric Constant (D 150 - 34 T), Solid Filling and Treating Compounds Used for Electrical Insulation (D 176 - 34 T), Sheet and Plate Materials Used in Electrical Insulation (D 229 - 34 T), Laminated Tubes Used in Electrical Insulation (D 348 - 34 T), Laminated Round Rods Used in Electrical Insulation (D 349 - 34 T), Flexible Varnished Tubing Used for Electrical Insulation (D 350 - 32 T), Test for Grading Natural Mica (D 351 - 33 T), for Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 34 T), and Specifications for Flexible Varnished Tubing Used in Electrical Insulation (D 372 - 33 T) were accepted, the methods and specifications, as revised, being continued as tentative.

The following two papers describing apparatus for determining the characteristics of insulating materials were presented by Mr. Dike and discussed:

"A Modified Schering Bridge," by W. B. Kouwenhoven, P. H. Dike and J. B. McCurley.

"The Transformer Bridge," by J. B. McCurley, W. B. Kouwenhoven and P. H. Dike.

The meeting then adjourned till 8 p. m.

TENTH SESSION—THURSDAY, JUNE 27, 8 P. M.

Effect of Temperature on Metals, Fatigue of Metals

(Held Simultaneously with Eleventh Session)

Mr. L. B. Tuckerman in the chair.

The report of the Joint Research Committee of A.S.M.E. and A.S.T.M. on Effect of Temperature on the Properties of Metals was presented by A. E. White. The proposed revision of the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 - 34 T) was accepted, the methods as revised being continued as tentative. In presenting the report, Mr. White called upon Mr. Dahle to present the "Report on Effect of Long-Time Heating With and Without Stress on Impact Resistance of 18 per cent Chromium, 8 per cent Nickel Steel (K9 and K19 Steel)," by H. C. Cross and F. B. Dahle.

A paper entitled "Some Tests on Tin Bronzes at Elevated Temperatures," by J. W. Bolton, was presented by the author and discussed.

A paper entitled "Influence of Time on Creep of Steels," by A. E. White, C. L. Clark and R. L. Wilson was presented by Mr. Clark and discussed.

A paper entitled "Creep Characteristics of Aluminum Alloys," by R. R. Kennedy, was presented by the author and discussed.

The report of the Research Committee on Fatigue of Metals was presented by the chairman, H. F. Moore. The Notes on Fatigue Tests on Rotating-Beam Testing Machines were accepted for publication as information.

A paper entitled "The Rotating-Wire Arc Fatigue Machine for Testing Small-Diameter Wire," by J. N. Kenyon, was presented by the author and discussed.

A paper entitled "High-Speed Fatigue Tests of Several Ferrous and Non-Ferrous Metals at Low Temperatures," by H. D. Boone and H. B. Wishart, was presented by Mr. Wishart and discussed.

The meeting then adjourned till the following morning.

ELEVENTH SESSION—THURSDAY, JUNE 27, 8 P. M.

Waterproofing, Road Materials, Soils

(Held Simultaneously with Tenth Session)

Mr. C. N. Forrest in the chair.

The report of Committee D-8 on Bituminous Waterproofing and Roofing Materials was presented by the chairman, J. M. Weiss. The recommendation presented by Committee D-8, in which Committee D-4 on Road and Paving Materials joined, that Group 0 and Group 1 in the Standard Abridged Volume Correction Table for Petroleum Oils (D 206 - 34) be tentatively approved as a Volume Correction Table for Asphaltic Products was accepted. The editorial changes in the Standard Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (D 173 – 27) were accepted.

The proposed revisions of the Tentative Specifications for Asphalt Roofing Surfaced with Powdered Talc or Mica (D 224 – 34 T), for Asphalt Shingles Surfaced with Coarse Mineral Granules (D 225 – 34 T), for Asphalt Roofing Surfaced with Fine Mineral Granules (D 248 – 34 T), for Asphalt Roofing Surfaced with Coarse Mineral Granules (D 249 – 34 T) and for Asphalt for Use in Constructing Built-Up Roof Coverings (D 312 – 29 T) with certain editorial changes presented on the floor at the annual meeting were accepted, the specifications, as revised, being continued as tentative. The proposed revision of the Tentative Method of Test for Coarse Particles in Bituminous Materials by Means of Elutriation (D 313 – 29 T) in the form of a Tentative Method of Test for Coarse Particles in Mixtures of Asphalt and Mineral Matter was accepted.

A paper entitled "A Study Concerning a Modification of the Present Miscibility Test and Its Relationship with Probable Settlement Results," by C. A. Downing, was presented by the author and discussed.

A paper entitled "Investigations of the Physical Properties of Asphaltic Mixtures at Low Temperatures," by L. F. Rader, was presented by the author and discussed.

Mr. J. M. Weiss then assumed the chair.

The report of Committee D-4 on Road and Paving Materials was presented by the vice-chairman, R. L. Morrison. The recommendation presented jointly by Committee D-4 and Committee D-8 on Bituminous Waterproofing and Roofing Materials that Group 0 and Group 1 in the Standard Abridged Volume Correction Table for Petroleum Oils (D 206 – 34) be tentatively approved as a Volume Correction Table for Asphaltic Products was accepted as referred to above.

The proposed Tentative Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates, recommended jointly by Committee D-4 and Committee C-9 on Concrete and Concrete Aggregates, was accepted for publication as tentative with the following modifications presented on the floor at the annual meeting:

Section 1.—Insert as a note to this section the explanatory statement appearing in the preprinted report of Committee D-4.

Section 4.—Change the first sentence in Paragraph (*c*) of this section from the form as preprinted, namely,

> The agitation shall be sufficiently vigorous to result in the decantation of all particles finer than the No. 200 (74-micron) A.S.T.M. sieve.

to read as follows:

> The agitation should be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the No. 200 (74-micron) A.S.T.M. sieve and bring the fine material into suspension in order that it will be removed by decantation of the wash water.

Change the last sentence of Paragraph (*d*) to read as follows by the addition of the italicized words and figures:

> The washed aggregate shall be dried to constant weight at a temperature not exceeding 110 C. (230 F.) *and weighed to the nearest 0.02 per cent.*

Section 6.—Change this section from the form as preprinted, namely,

> 6. When check determinations are desired, the wash water shall be evaporated to dryness, the residue weighed and the percentage calculated from the following formula:

to read as follows:

> 6. When check determinations are desired, the wash water shall be either evaporated to dryness or filtered through tared filter paper which shall subsequently be dried, the residue weighed and the percentage calculated from the following formula:

The proposed editorial change in the Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 30) was accepted. The proposed revision of the Tentative Methods of Test for Residue of Specified Penetration (D 243 - 32 T) and of Testing Emulsified Asphalts (D 244 - 34 T) were accepted, the methods as revised being continued as tentative.

The Tentative Method of Test for Ductility of Bituminous Materials (D 113 - 32 T) was approved for reference to letter ballot of the Society for adoption as standard with the following changes presented on the floor at the annual meeting:

Section 2.—Delete the proposed revision in this section which appeared in the report as preprinted.

Add the following as a footnote in connection with Section 2 and Fig. 1:

> The over-all dimension of 11.9 cm. ± 0.1 cm. in Fig. 1 shall be waived until January 1, 1939, provided the actual dimension is between 11.2 and 11.9 cm. This exception is allowed in order to avoid working a hardship upon apparatus manufacturers.

The Proposed Method of Test for Abrasion of Coarse Aggregate, presented on the floor at the annual meeting, was accepted for publication in the report as information.

It was announced that the committee had completed the preparation of eight proposed methods of test for sampling, analyzing and testing soils which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

The following two papers on the subject of soil testing were then presented by their authors and discussed:

"Stability of Granular Mixtures," by D. S. Berry.

"A Penetration Method of Measuring Soil Resistance," by W. S. Housel.

A paper entitled "The Los Angeles Abrasion Machine for Determining the Quality of Coarse Aggregate," by D. O. Woolf and D. G. Runner, was presented by Mr. Woolf and discussed.

The meeting then adjourned till the following morning.

TWELFTH SESSION—FRIDAY, JUNE 28, 9.30 A. M.

Spectrographic Analysis

(Held Simultaneously with Thirteenth Session)

President Hermann von Schrenk in the chair.

The report of Committee E-2 on Spectrographic Analysis was presented by the chairman, H. V. Churchill. It was announced that the committee had completed the preparation of Methods of Test for Quantitative Spectrochemical Analysis of High-Grade Pig Lead for Copper, Bismuth, Silver and Nickel, for Quantitative Spectrochemical Analysis of Zinc Alloy Die Castings for Minor Constituents and Impurities, and for Quantitative Spectrochemical Analysis of Zinc for Lead, Iron and Cadmium which, if approved by letter ballot of the committee, would be submitted to the Society through Committee E-10 on Standards for publication as tentative subsequent to the annual meeting.

Mr. H. V. Churchill then assumed the chair.

Mr. Churchill in introducing the Symposium on Spectrographic Analysis stated that the program had been arranged under the auspices of Committee E-2 on Spectrographic Analysis, with two principal objects in view: first, to give those who are working in this field definite information as to the methods used by those who are depending upon spectrographic analysis for the control of quality in a variety of industries; and second, to indicate to those not actually engaged in spectrographic work, but interested in the possibility of securing more rapid and reliable methods of testing, the fact that numerous laboratories have found in the spectrograph an invaluable tool that will shorten the time required for analyses and give more complete and definite information as to the composition of materials than can be obtained in any other way. It was hoped, as a result of the information made available through the symposium, to create a wider interest and confidence in spectrographic methods as a reliable means for inspecting various materials to determine their conformity to standard specifications.

The symposium, which comprised the following papers describing methods and details of procedure which have been found applicable to the analysis of various metals, both ferrous and non-ferrous, was then presented from manuscript:

"Spectrographic Analysis of Steel Samples," by W. R. Brode, presented by the author.

"The Use of the Spectrograph in the Platinum Industry," by H. E. Stauss, presented by the author.

"Quantitative Spectrographic Analysis of Magnesium Alloys for Manganese and Silicon," by J. S. Owens and T. M. Hess, presented by Mr. Owens.

"The Spectrographic Determination of Impurities in Commercial Cadmium," by Frances W. Lamb, presented by the author.

"The Purification of Graphite Electrodes for Spectrochemical Analysis," by G. W. Standen and L. Kovach, Jr., presented by M. L. Fuller.

"Quantitative Analysis of Non-Ferrous Alloys by Spectroscopic Methods," by R. A. Wolfe, presented by the author.

Following their presentation the papers were discussed.

The meeting then adjourned till 2 p. m.

THIRTEENTH SESSION—FRIDAY, JUNE 28, 9.30 A. M.

Ceramics, Refractories, Masonry Materials

(Held Simultaneously with Twelfth Session)

Past-President T. R. Lawson in the chair.

The report of Committee C-3 on Brick was presented by J. W. McBurney. The proposed revisions of the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30) in the form of separate tentative specifications, and of the Standard Methods of Testing Brick (Compression, Flexure, Absorption) (C 67 – 31) in the form of separate tentative methods, were accepted for publication as tentative. Mr. McBurney also presented his paper entitled "The Relation of Freezing and Thawing Resistance to Physical Properties of Clay and Shale Building Brick," which was appended to the report, and then called upon Mr. Parsons to present the report of Subcommittee XI on Weathering and Porosity and a paper entitled "Comparison of Natural Weathering with Laboratory Tests of Clay Brick," by D. E. Parsons.

A paper entitled "Pre-Stressed Ceramic Members," by F. O. Anderegg and C. L. Dalzell, was presented from manuscript by Mr. Anderegg and discussed.

A paper entitled "Tests of Mortars for Reinforced Brick Masonry," by M. O. Withey and K. F. Wendt, was presented by Mr. Withey and discussed.

The report of Committee C-10 on Hollow Masonry Building Units was presented by the chairman, D. E. Parsons. The proposed revisions of the Tentative Specifications for Structural Clay Floor Tile (C 57 – 34 T), for Structural Clay Non-Load-Bearing Tile (C 56 – 34 T), for Structural Clay Load-Bearing Wall Tile (C 34 – 34 T) and Methods of Sampling and Testing Structural Clay Tile (C 112 – 34 T) were accepted, the specifications and methods as revised being continued as tentative. It was announced that the committee had prepared additional revisions of each of these four tentative standards which, if approved by letter ballot of the committee, would be submitted to the Society through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "A Wear Test for Flooring Materials," by J. R. Shank, was presented by the author and discussed.

A paper entitled "A Test Procedure for Plastic Caulking Materials," by D. W. Kessler, was presented by the author and discussed.

The report of Committee C-4 on Clay Pipe was presented by the chairman, G. T. Hammond. The Tentative Specifications for Clay Sewer Pipe (C 13 – 33 T), as revised, were approved for reference to letter ballot of the Society for adoption as standard, with the following additional changes presented on the floor at the annual meeting to correct typographical errors appearing in the existing specifications:

Table II.—In the third column showing the inside diameter at ½ in. above base of socket, change the dimension for the 18-in. size pipe from "22½ in." to read "22¼ in."; and for the 21-in. size change "25¾ in." to read "25⅞ in."

The proposed revision of the Standard Definitions of Terms Relating to Sewer Pipe (C 8 – 24), in the form of separate tentative definitions, was accepted for publication as tentative.

The report of Committee C-8 on Refractories was presented by the secretary, C. E. Bales. The proposed Tentative Definitions of Terms Relating to Refractories were accepted for publication as tentative. The definition of "Super Duty Fire-Clay Brick," was accepted for publication as a tentative revision of the Standard Definitions for Clay Refractories (C 27 – 28). The Tentative Definitions of Terms Relating to Refractories (C 71 – 34 T) and Method of Chemical Analysis of Magnesite Refractories (C 18 – 34 T), to be incorporated in the existing standards on these subjects, were approved for reference to letter ballot of the Society for adoption as standard. The tentative revisions of the Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 – 33) and Definitions for Clay Refractories (C 27 – 28) were approved for reference to letter ballot of the Society for adoption as standard.

The meeting then adjourned till 2 p. m.

FOURTEENTH SESSION—FRIDAY, JUNE 28, 2 P. M.

Non-Ferrous Metals, Metallography

Mr. H. A. Anderson in the chair.

The report of Committee B-1 on Copper Wire was presented by the chairman, J. A. Capp. The proposed revisions of the Standard Specifications for Bare, Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 27) and for Bronze Trolley Wire (B 9 – 32), in the form of separate tentative specifications, were accepted for publication as tentative. The proposed revision of the Standard Specifications for Copper Trolley Wire (B 47 – 32) was also accepted for publication as tentative.

The report of Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys was presented by the chairman, Dean Harvey. The proposed revision of the Tentative Method of Test for Linear Expansion of Metals (B 95 – 34 T) was accepted, the method as revised being continued as tentative.

The report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, was presented by W. B. Price. The proposed Tentative Specifications for Copper-Silicon Alloy Wire for General Purposes and for Wrought Phosphor-Bronze Bearings and Expansion Plates for Bridges and Structures were accepted for publication as tentative. The proposed Tentative Specifications for Wrought Silicon-Bronze Bearings and Expansion Plates for Bridges and Structures, which appeared in the report as preprinted, were discussed and, on motion, were referred back to Committee B-5 for further consideration.

It was announced that the committee had completed the preparation of new Specifications for Hard-Drawn Copper Alloy Wires (for Electrical Distribution and Transmission Line Purposes) and had prepared a revision of the new Tentative Specifications for Copper Silicon Alloy Wire for General Purposes which, if approved by letter ballot of the committee, would be submitted to the Society for publication as tentative through Committee E-10 on Standards subsequent to the annual meeting.

A paper entitled "A Survey of Testing in the Precious Alloy Field, with Some Notes on the Testing Requirements for Duplex Alloys," by Thomas A. Wright, was presented by the author and discussed.

The report of Committee E-4 on Metallography was presented by the chairman, C. H. Davis. The proposed revision of the Standard Methods of Metallographic Testing of Iron and Steel (E 3 – 24) and of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 27), in the form of a Tentative Recommended Practice for Metallographic Testing of Ferrous and Non-Ferrous Metals, was accepted for publication as tentative.

The report of Committee B-6 on Die-Cast Metals and Alloys was presented by the chairman, J. R. Townsend. The proposed Tentative Specifications for Lead and Tin-Base Alloy Die Castings were accepted for publication as tentative. In presenting the report Mr. Townsend called attention to the work of Subcommittee I on Aluminum Base Die-Casting Alloys and stated that the report prepared by J. J. Bowman entitled "An Investigation of Aluminum Die-Casting Alloys IVa and Va," had been accepted by the committee for inclusion in its annual report but had not been preprinted. A discussion of this report was presented. Mr. Townsend also announced that Subcommittee V on Exposure and Corrosion Tests under the chairmanship of W. M. Peirce had completed the testing of the specimens from the 5-yr. indoor and outdoor corrosion racks, covering both zinc and aluminum alloys, and that the tabulated data on these studies had been accepted for inclusion in the report of the committee but had not been preprinted.

The report of Committee B-2 on Non-Ferrous Metals and Alloys was presented by the secretary, E. E. Thum. The proposed Tentative Specifications for Lead-Coated Copper Sheets were accepted for publication as tentative. The proposed revision of the Standard Specifications for Slab Zinc (Spelter) (B 6 – 33) was accepted for publication as tentative. The Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 33 T), as revised, and the Tentative Specifications for Pig Lead (B 29 – 34 T) were approved for reference to letter ballot of the Society for adoption as standard. The tentative revision of the Standard Methods of Chemical Analysis of Manganese Bronze (B 27 – 19) was approved for reference to letter ballot of the Society for adoption as standard.

A paper entitled "Making and Testing Single Crystals of Lead," by B. B. Betty, was presented by the author and discussed.

The meeting then adjourned till 8 p. m.

FIFTEENTH SESSION—FRIDAY, JUNE 28, 8 P. M.

Cement, Lime, Concrete

Mr. M. O. Withey in the chair.

The report of Committee C-1 on Cement was presented by the chairman, P. H. Bates. A motion for the adoption as standard of the Tentative Specifications for High-Early-Strength Portland Cement (C 74 – 30 T), as revised, after discussion failed to receive the necessary two-thirds vote of those voting at the session, which is required for referring it to letter ballot of the Society, the results of the vote being 34 affirmative and 27 negative.

A paper entitled "Classification of Hydrated Limes by a Mobilometer," by T. G. Dixon and J. R. Withrow, was presented from manuscript by Mr. Withrow.

An informal report of the Sectional Committee on Specifications for Plastering, F. Leo Smith, acting chairman, was presented by the Assistant Secretary.

A verbal progress report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete was presented by the secretary, F. R. McMillan. The Joint Committee recommended the withdrawal of the Tentative Rules for Inspection of Concrete and Reinforced Concrete Work (C 44 – 22 T).

The report of Committee C-13 on Concrete Pipe was presented by the chairman, A. E. Phillips. The proposed Tentative Specifications for Concrete Irrigation Pipe were accepted for publication as tentative. The proposed revision of the Tentative Specifications for Reinforced Concrete Culvert Pipe (C 76 – 30 T) was accepted, the specifications as revised being continued as tentative. The Tentative Specifications for Non-Reinforced Concrete Sewer Pipe (C 14 – 34 T), to supersede the existing standard specifications, and for Reinforced Concrete Sewer Pipe (C 75 – 34 T), as revised, were approved for reference to letter ballot of the Society for adoption as standard.

A paper entitled "Research on Concrete Disintegration," by H. S. Mattimore and G. A. Rahn, was presented by Mr. Mattimore and discussed.

Mr. J. C. Pearson then assumed the chair.

The report of Committee C-9 on Concrete and Concrete Aggregates was presented by the chairman, R. W. Crum. The proposed Tentative Methods of Making Compression Tests of Concrete Using Portions of Beams Broken in Flexure and of Determining Voids in Coarse Aggregate were accepted for publication as tentative. The proposed Tentative Method of Test for Material Finer than No. 200 Sieve in Aggregates, recommended jointly by Committee C-9 and Committee D-4 on Road and Paving Materials, was accepted for publication as tentative with certain modifications[1] presented on the floor at the annual meeting, subject to favorable letter ballot of Committee C-9.[2]

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[1] These changes appear on page 19.

[2] The proposed revision was submitted to letter ballot of Committee C-9 which consists of 59 members; 42 members returned their ballots, of whom 38 voted affirmatively and none negatively.

The proposed revisions of the Tentative Methods of Test for Soundness of Fine Aggregates by Use of Sodium Sulfate (C 88 – 32 T) and for Soundness of Coarse Aggregates by Use of Sodium Sulfate (C 89 – 32 T), to provide also for the use of magnesium sulfate in determining the soundness of aggregates were accepted, the methods as revised being continued as tentative. The proposed revision of the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 33) was accepted for publication as tentative with the addition of a reference to the new Tentative Method of Test for Amount of Material Finer Than No. 200 Sieve in Aggregates.

The Tentative Specifications for Ready-Mixed Concrete (C 94 – 33 T), as revised, was approved for reference to letter ballot of the Society for adoption as standard, with the following additional modifications presented on the floor at the annual meeting, subject to favorable letter ballot of Committee C-9:[1]

Section 13.—In place of the clause recommended in the preprint of the report to be added after the word "materials" in this section, which read as follows:

"care should be exercised to see that the hopper is completely emptied during the discharge of the cement"

substitute the following clause:

"the entire contents of the hopper shall be completely discharged"

Section 19.—Change the fourth sentence to read as follows by the addition of the italicized words and the omission of the words in brackets:

The mixing time shall be measured from the time that all [dry materials] *cement and aggregates* are in the mixer.

Section 22.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

22. Concrete shall be delivered to the site of the work, and discharge from the hauling container shall be [begun] *completed* within a period of 1½ hr. after the introduction of the mixing water to the [dry materials], *cement and aggregates*, or the cement to the aggregate [if] *when* the fine aggregate contains [surface] moisture in excess of 6 per cent by weight [or] *and* the coarse aggregate contains [surface] moisture in excess of 3 per cent by weight.

In presenting the report Mr. Crum summarized briefly the paper entitled "Methods of Test for Determining Volume Changes in Concrete," by Raymond E. Davis, appended to the report, and then called upon Mr. Leavitt to present the report of Subcommittee XI on Evaluation of Data comprising "A Statistical Study of Bulk Specific Gravity and Mechanical Analysis Tests of Samples of Fine and Coarse Aggregate," and also a paper, not included in the report as preprinted, entitled "Comparisons of Different Types of Specimens for Compression Tests of Mortar," by H. J. Gilkey and H. Walter Leavitt.

A paper entitled "Determination of Modulus of Elasticity and Poisson's Ratio of Concrete at Ages of Fourteen Days to Four Years," by L. H. Koenitzer, was presented by C. H. Scholer.

A paper entitled "The Chemistry and Physics of Concrete Shrinkage," by R. W. Carlson, was presented from manuscript by the author and discussed.

A paper entitled "Shrinkage of Concrete," by Inge Lyse, was presented from manuscript by the author and discussed.

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[1] The proposed revision was submitted to letter ballot of Committee C-9 which consists of 59 members; 42 members returned their ballots, of whom 38 voted affirmatively and none negatively.

A vote of thanks was extended to the Detroit Committee on Arrangements for their untiring efforts in planning the program, assisting with the Exhibit, and in making the necessary arrangements for entertainment of the ladies and other activities which contributed greatly to the success of the annual meeting, the third largest in the history of the Society from the standpoint of registered attendance.

There being no further business the chairman then declared the Thirty-eighth Annual Meeting adjourned *sine die.*

ANNUAL ADDRESS BY THE PRESIDENT

Hermann von Schrenk

June 25, 1935

In his annual address, the President is usually expected to present a brief statement concerning the activities of the Society during the past year. However, these activities are so fully covered in the annual reports of the Executive Committee and other administrative committees that I shall reserve to myself mention in this regard of just a few things I should like to emphasize.

First, I wish to call attention to the question of membership. While our growth in membership during the past year has been very gratifying, with resultant increase in available funds, we are still hampered in our activities because of lack of funds in the treasury. The various phases of activity in which our Society is engaged are growing rapidly from year to year, and, as the work of the A.S.T.M. is appreciated more and more, demands are being made upon the Society through its committees and through its general office which we shall be unable to meet. In fact, we have reached a point where it will mean either standing still, or curtailing some of our essential activities. I would repeat, therefore, the request of my predecessors in office, that everyone in the Society do his best to assist in increasing our membership.

It is with pleasure that I report increased cooperation with other technical bodies. There are many engineering, architectural, contracting and even governmental organizations interested in the use of materials. In the beginning, all of these organizations started to write specifications and methods for testing. It is becoming more and more widely recognized that, of all the engineering bodies, the A.S.T.M. is the one best fitted to write specifications and methods for testing because of its country-wide research connections and its machinery for handling the results of research. The A.S.T.M. is being repeatedly asked to sponsor the development of specifications. During the past year, a very important meeting of Committee E-10 on Standards was held with the Standards Committee of the American Railway Engineering Association. A very full discussion took place dealing with the relationship between this great railroad organization and the A.S.T.M. It is confidently expected that, as a result of this meeting, official representatives of the railway organization will be delegated to serve on various committees of our Society.

I have been greatly impressed in late years with the fact that several of the most important sessions of our annual meetings are poorly attended by the membership. The annual meeting has become more and more an occasion for committee meetings. This is natural, particularly in late years when it has been increasingly difficult for the committees to meet as frequently as was their custom. The holding of so many committee meetings during the annual meeting has resulted in a very slight attendance at the opening session and has also reduced the number of members who find it possible to attend the general sessions. The annual meeting was thus in danger of becoming a convention of committee meetings. It is generally recognized by the Executive Committee that committee work is, after all, the foundation of the Society's efficiency and that nothing must be done to restrict unduly the opportunity for holding committee meetings. Nevertheless, it was felt that there should be certain periods during the week when no committee meetings should be held; and in addition to the periods occupied by the Marburg lecture and the dinner, which have by custom been free of committee meetings, no meetings of committees are being held during the opening session and only a few unavoidable ones during the symposium this evening. The officers and members of the Executive Committee very much appreciate the cooperation of the members in conforming to this arrangement.

This is our THIRTY-EIGHTH ANNUAL MEETING. This year, we have assembled in a great industrial city, where the significance of the work of the A.S.T.M. needs no advertising. During the past thirty-seven years our Society has done an enormous amount of work dealing with engineering materials, describing the qualities which make them fit for use, and developing methods for testing the physical and chemical properties of such materials. We now have 306 standard and 135 tentative specifications, or a total of 442 specifications; also 168 standard and 93 tentative standard methods of test, or a total of 261 methods. In addition, there are 29 lists of definitions. This imposing development, representing as it does the intensive work of both producers and consumers, has been made possible only by close cooperation between such industries as are represented in Detroit and elsewhere, together with research institutions all over the country.

Let me stress the point that the committees of our Society are essentially research organizations. The formation of a standard, therefore, does not necessarily mean that it remains put. One of the outstanding functions of the A.S.T.M. is to keep these standards in a "fluid" condition so that as the demands of the consumers change, or as use determines the necessity for revision of standards or methods of testing, such changes can rapidly be made. While this may be an old story to some of you, I believe the following figures are impressive. We now have 53 standing committees, 6 research and joint committees and 17 sectional committees, or a total of 76 committees. The Society has appointed official representatives on 51 committees of other organizations and, in addition to this, the Society has appointed representatives on 5 American Standards Association administrative committees; 2 advisory committees of the National Bureau of Standards; 4 committees of the International Standards Association and 10 study committees of the International Association for Testing Materials.

Of necessity, the work of our committees is becoming more complex and more intensively specialized. When committee work started, all members of a committee were more or less active in the consideration of all the problems with which the committee dealt. This is now neither possible nor practicable. For one reason or another, there has been a degree of specialization which has necessitated the handling of specific phases of one or more problems by subcommittees composed of men who are trained specially in those particular phases. In the following, I refer to a few of our committees, giving the total number of members, number of subcommittees and year organized:

	Number of Members	Number of Sub-committees	Year Organized
A-1 on Steel	200	20	1898
A-5 on Corrosion of Iron and Steel	127	7	1906
B-2 on Non-Ferrous Metals and Alloys	100	10	1909
D-1 on Preservative Coatings for Structural Materials	157	16	1902
D-2 on Petroleum Products and Lubricants	107	30[a]	1904
D-13 on Textile Materials	154	21	1914

[a] 26 subcommittees; 4 technical committees.

I need not point out any of the lines of investigation leading to the writing of specifications in which these committees are involved. I refer you to the Year Book of the Society. I have mentioned the above to prepare you for what follows.

I made the statement that at the beginning all members of a committee dealt with all problems, largely because they were able to grasp the significance of the various questions presented and to treat them with understanding. As the years have gone on, information and knowledge has become more and more special so that often members of the same committee do not understand each other. I am speaking from personal experience when I say that if they understand each other, their understanding may be more or less nebulous. This of course is in line with all advancement in knowledge. I have never forgotten an experience which took place at Yale University many years ago at an annual dinner meeting at which representatives of all the pure sciences were present. Professor Brewer of Yale (one of the Deans of American Science) was called on for a few remarks. He started by describing his visit to the sessions of the Geological group:

"After listening for awhile" he stated, "I did not understand a word of what they were talking about." He then visited the sessions of the sections on Zoology, Botany, Physics and Chemistry, at all of which he had the same experience. He ended his brief address with this statement . . . "and to think, gentlemen, that thirty years ago I was a Professor of Geology, Zoology, Botany, Physics and Chemistry at Yale College."

As one of the older members of the A.S.T.M., I find myself very much in the same position as Dr. Brewer and doubtless many of my confreres of early years are having the same experience. What is true of our understanding of the present state of knowledge of very broad phases is equally true when it comes to more special branches. I should like to think that all the two hundred members of Committee A-1 on Steel, or the one hundred and fifty-seven members of Committee D-1 on Preservative Coatings are equally informed as to the respective state of knowledge of the material subject to the work of their committee. Be that as it may, I feel very positive that many members of Committee D-1 know very little about what is going on or what has been accomplished by the members of Committee A-1 and *vice versa*. I make my apologies to the members of these two committees; in singling them out, I am using them simply as an illustration. The comparison will hold equally for all committees.

You may ask—what does this have to do with the A.S.T.M. and its work? The answer is this: I have felt for a long time, that in common with other great research bodies, the time has come when we should sit down occasionally and consider where we are going. The American Association for the Advancement of Science, with its huge membership and its large number of affiliated national scientific bodies, started an idea some years ago which, for want of a better term, I shall call the "Symposium Idea." They picked out subjects of interest to a considerable number of groups; for instance, a subject the various phases of which could be discussed by specialists of Zoology, Genetics, Botany, Paleontology, etc. The idea was to give a general survey so that the members of these groups as well as the public at large might have a better vision of the results of investigations up to the time of presentation. At every annual convention, a large number of symposia appear on the program. These discussions have added greatly to the interest of the meetings and have proven of great value both to the participants as well as to the hearers. Our Society has had symposia, too, but in the main they have dealt with materials assigned to one committee or one group within the Society, such as rubber, paint, corrosion, to name the topics discussed at some of the A.S.T.M. Regional Meetings in recent years. The Symposium on Aircraft Materials[1] at the 1930 annual meeting and the Symposium on Developments in Automotive Materials held at the 1930 Regional Meeting in Detroit represents perhaps the closest parallel in our history to the type of symposium to which I refer, in that they brought together the experts on *different* materials that are involved in the construction of aircraft. As I shall point out later, I should like to see this idea developed in such a way as to bring our *committees* rather than individual experts into direct participation in such symposia.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 26 (1930).

I confess that I have often wondered where all this increasing knowledge is going to lead. I picture the A.S.T.M. for instance, as consisting of a large wheel with many spokes, but without a rim! The hub is the mass of the Society membership. From it spring the spokes going in every direction. These spokes increase in length representing the increase in knowledge, and specifically the increase in the number of specifications developed. These spokes may then be imagined as dividing. At the present time, we have 53 main spokes and some of these main spokes have as high as 30 divisions. I picture the situation of the individual member (and this will apply equally to the consumer or prospective user of our specifications) at the end of one of these spokes, or one of the sub-spokes, looking about him with some bewilderment, conscious or otherwise, at his immediate neighbors who have travelled up some of the adjacent spokes, to say nothing of those who have travelled up the spokes on the opposite side of the hub. As I stated at the outset, this wheel has no rim and the one at the end of one spoke therefore has no short cut to his neighbors at the end of the other spokes. I trust you will pardon this visualization. It leads to this suggestion, it appears to me, that the time has come when we should pause occasionally and attempt a tying together of the very divergent results of our investigations. To continue the visualization, what I should like to see is the development of an occasional rim. The symposium idea has always appealed to me because it brings people of different lines of thinking together and, on such an occasion, they can explain what they have done and what they expect to do.

You may ask why I am so strongly stressing the idea of getting together people of diverse interests. I shall give you an answer to this question in the second portion of my talk. Let it be said at this point, however, that a broader understanding of subjects, both those closely related as well as those distantly related, has always helped the man in the prosecution of his own specialty. It makes possible a broader outlook and generates sympathetic understanding. At the first meeting of the Executive Committee this year, I suggested that we try to have a symposium at this annual meeting in Detroit of the kind I have described. The Executive Committee and the Detroit Committee on Arrangements favored the idea with the result that this evening we are to hold a Symposium on the Place of Materials in Automobile Roads and Rides. I hope you will all be there, not only to listen, but to take part in the discussion. The subject chosen is one typifying the great industries of this city. Frankly, it is an experiment; maybe after we have tried this experiment for a few years it will work even better. I have no fear we will ever exhaust the possibility of finding subjects for such symposia. If you had all attended the first meeting of the Detroit Committee and could have heard the suggestions for a subject for this symposium, you would share my optimism. I close this phase of my presentation with the statement that there is no engineering body that I know of in the world which has the breadth of field, the amount of knowledge, and the personnel able to discuss materials of engineering in such symposia as has the A.S.T.M.

I do not think that I am wrong in my conclusions that the symposium will make for a broader understanding of our work, both so far as the members are concerned as well as the public who use our specifications.

What starts the preparation of a specification? Briefly stated, this may come because of a definite consumer demand for a definite article, or, it may be the demand of a producer of an article to assist in a clear definition of the article produced. The specification may be either for the material itself or for the process to improve a given article. As an example, we are now endeavoring to develop specifications for galvanizing, that is, a method for improving the corrosive resistance of steel. Similarly, we write specifications for paint which reduces weathering, and we write specifications for coal tar creosote to improve the lasting power of wood. In its last analysis, the animating factor uppermost both in the demand for a specification and in its preparation, is that the material or the process shall make the material the best to be used for a specific purpose. In other words, I stress the USE requirement.

Let me illustrate this. On the railroads, we use millions of spikes to hold the rails at a uniform distance from one another or, as the railroad engineer states it, "to maintain gage." These spikes are usually made of steel. They are driven into crossties which formerly lasted ten years, we will say. We now creosote the ties using creosote examined and tested under A.S.T.M. specifications. These ties will last thirty years or more. On the rails we run refrigerator cars from which brine leaks and falls on to these spikes causing rapid corrosion. A careful study has been made to determine whether this dripping of brine might be prevented by holding the brine in the refrigerator car and dumping it at designated places, so that it will not come in contact with bridges or track. The cost of this method is prohibitive. We must now do something. We must either use some other metal or do something with the spikes to make them last 30 years if possible, because it is obviously uneconomical to have one element in a structure function a shorter period than the remainder if it can possibly be avoided. What happens? The Society also writes a specification for zinc coating. The Society writes specifications for testing the steel and the zinc. In none of these specifications is there a word indicating a possible relationship one to the other.

As one interested in the use of wood, I shall give you another example: How many of you know how many A.S.T.M. specifications and methods of testing are involved when anyone builds a wooden house? Without going into the matter in too detailed a manner, I list the following which will at once occur to any one of you:

LIST OF MATERIALS THAT CAN BE USED IN THE DESIGN AND CONSTRUCTION OF A HOUSE

		COMMITTEES INVOLVED
I-Beams	Structural steel	A-1
	Light alloy shapes	B-7
Alloy steel		A-10
Pipe	Ferrous	A-1, A-2 and A-3
	Copper and brass	B-5
Nails-bolts-screws, etc., both metallic coated and uncoated		A-1, A-5, B-5, Sectional Committee on Zinc Coating
Copper gutters and spouts		B-5
Die castings, fixtures, etc		B-6
Copper wire screening		D-14
Lumber and timber		D-7
Brick (house and chimney)		C-3 and C-8
Stone		C-18
Tile, structural clay		C-10
Plaster	Lime	C-7
	Gypsum	C-11
Mortars		C-12
Cement		C-1
Concrete		C-9
Concrete reinforcement		A-1
Drain tile		C-4
Wall board and lath		C-11
Electric wiring	Bare wire and cable	B-1
	Insulated wire and cable	D-11
	Tape	D-11
Roofing	Metallic	A-1, B-2 and B-5
	Non-Metallic, roll roofing, shingles, etc	D-8
	Slate	D-16
	Tile	C-10
	Waterproofing materials	D-8
Protective coatings for wood		D-1
Protective coatings for metal		A-5, Sectional Committee on Zinc Coatings
Fire protection		C-5

The Secretary has sent me a list of 96 specifications which enter into the building of such a structure. I take as an example, the owner who is about to construct a wooden house. He employs an architect or contractor, who may specify the proper A.S.T.M. structural wood grades, that is, the kinds of timber to be used for beams and two-by-fours. The A.S.T.M. has no specifications for siding, lath, flooring or shingles. The various items of wood are to be held together by means of nails. In the current Book of A.S.T.M. Standards, I can find no specifications whatsoever for either steel, galvanized or iron nails, so the contractor or architect will probably take the easiest way and specify steel nails, which are the most common article of commerce. In the course of time, sometimes after only a few years, the steel nails, particularly those exposed out of doors, such as those which hold the siding or shingles, will rust and ultimately give way. In due course of time the siding may fall off or the shingles blow away and all sorts of troubles develop for the owner.

I cite the case of the wooden shingle, particularly, because it is so startling an illustration of what I have in mind. Wooden shingles were among the earliest roof coverings used. When made of naturally long-lived woods such as cypress, cedar, redwood, white pine, etc., they lasted for generations. With the advent of competitive roofing materials, various investigators found that the wooden shingle had a great advantage over others due to the slow heat transmission, that is, the wooden shingle gave a more comfortable house in summer and one requiring less fuel in winter. A hundred years or so ago, wooden shingles were fastened to a roof with blacksmith iron shingle nails which were then, as now, called "puddled iron shingle nails." I personally removed some of these several years ago from Mt. Vernon, the home of George Washington, which were in as good condition as when originally placed. Needless to say, the shingles were held in position by these nails and none of them blew away. This is not the case nowadays. The wooden shingle is usually fastened with a steel wire nail, and in a very short time these nails corrode and let go between the board and the shingle, with the result that the shingle slides off the roof or blows away and the roof leaks. Of far more significance, however, is the resultant fire hazard due to this failure on the part of the nails. Everyone knows that wood burns. When a fire occurs in a house or in a neighboring house, loose shingles are apt to become ignited by flying sparks if the shingles are not held firmly to the roof. The burning shingles are apt to fly off and ignite other houses. This is what is commonly known, in insurance language, as "the flying brand hazard" of the wooden shingle. I have personally examined thousands and thousands of shingles in years gone by and have reached the conclusion that the reason they become flying brand hazards has nothing to do with the use of wood in the form of a shingle, but is due to the corrosion of the nail which held the shingle. The heads of these nails turn into pin points, and, at the same time, the hole through which the nail extends becomes enlarged by some process of disintegration of the wood fiber which occurs however only when the nail rusts. I have never seen this happen with cut iron or galvanized steel nails.

What is the result of this failure to perform on the part of the corroded nail and wooden shingle? Laws have been passed at the instance of Insurance Underwriting bodies in practically every State of the Union, and, if not for the state, for practically all the larger communities, outlawing the use of the wooden shingle. Every citizen will agree with this restriction because, after all, we want to build a house so as to avoid fire hazard whenever possible. The prohibition against wood shingles has meant the loss of a valuable structural item efficient in every respect except its "staying put" and that failure was due to the fastening. All of this has happened because of failure to correlate the qualities of the metals involved in relation to the use to which they were to be put. What I have said about the wooden shingle and the steel nail applies equally to the siding and the nails which hold it. It applies to bolts and screws used in freight car construction. If I had the time, I should like to give you a detailed analysis of every one of the 96 specifications which the Secretary has listed which enter into the building of a house, in order to illustrate that there are relations of equal significance between the qualities of other building materials such as defined in our A.S.T.M. specifications, and their ability to function together in the best possible manner, in order to produce a good house.

My thesis is that practically every construction project involves the use of several materials. The type of material selected must depend on its fitness for use, not only because its own qualities make it fit, but because these qualities permit of the best use of other materials used in the same structure. No matter how good the specifications may be or how carefully they are followed for one class of material, they become useless if that material will not work in conjunction with others. Please understand clearly that I am not arguing that the A.S.T.M. should develop designs or should specify uses, but I do feel that every once in a while there should be some informational presentation which will indicate to the prospective user, first: what A.S.T.M. specifications exist with reference to various kinds of uses and, second: what the reasons are as to why certain A.S.T.M. specifications should be considered for the use of such material. In this connection, I call attention to the fact that while we cannot write specifications dealing with design, we can give information as to permissible and proper uses. This has been done in the past by a number of A.S.T.M. committees. I shall pick out one or two at random. Committee A-1 on Steel, for instance in its specifications for alloy-steel bolting material for high-temperature service (A 96 – 33) has a note as to the relation between allowable pressures and their corresponding allowable temperatures.[1] The same has been developed for carbon-steel castings for valves, flanges and fittings for high-temperature service (A 95 – 33); also for cast-iron wheels (A 46 – 24). In the latter case, information is given to the user showing the relation between diameter of the wheel, standard for maximum load per wheel and estimated weight. Jumping to timber, Committee D-7 prepared a rather lengthy informational Appendix to the specifications for structural timbers for detailed information as to allowable stresses as worked out by the Forest Products Laboratory and factors of immediate significance to the architect or builder. The specification, without this, would have meant practically nothing. In line with this idea, I call attention to the previously mentioned list of specifications concerned in the building of a house. I do not know how many architects in the United States have lists of this character in their files. It seems to me that this list would make a brave beginning which could be presented in the form of a printed analysis, if sufficient amount of informational matter were prepared, if you please, by all the committees involved or such as are pertinent, which would give a picture to the architect as to why the A.S.T.M. specifications should be used. In other words, what I am pleading for is an occasional informational presentation which will tie in our various standards because, as I said at the beginning of this phase of my discussion, the use feature is, after all, the proof as to the fitness of our standards.

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[1] See 1933 Book of Standards, Part I, p. 258.

I have always considered it a great privilege to be a member of the A.S.T.M. I have not only come in closer touch with men interested in my own field, but have obtained a wider range of vision. It has been well said that the art of engineering involves man's use, in the best possible manner, of the materials which Nature has placed at his disposal. To me, the significance of the A.S.T.M. is not only the investigation of the physical, chemical and biological qualities of these materials, but, by inference, the dissemination of knowledge as to their best use. My suggestions today hint at the possibility that there may be ways and means by which we can aid not only in spreading the knowledge of the accomplishments of the A.S.T.M. in writing specifications, a development of which we are justly proud, but by going a step farther in elucidating the significance and relationship of these specifications as fit for ultimate use, so that they may become increasingly incorporated in engineering work.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The Executive Committee offers the following report on general Society activities for the year ending with this annual meeting:

Membership:

The membership of the Society on June 1, 1935, was 3612. Statistics showing gains and losses in the various classes of membership are as follows:

Class of Membership	Membership		Losses				Additions		Totals		
	June 1, 1934	June 1, 1935	Resignations	Dropped	Death	Transfer	Transfer	Election	Loss	Gain	Increase
Honorary	2	2	...	...	..	..	..	...	...	...	..
Life or Perpetuity	11	11	...	...	..	..	..	...	...	...	..
Sustaining	6	8	...	...	..	..	1	1	...	2	2
Company, Firm, etc.	856	870	30	22	..	3	5	64	55	69	14
Individual, etc.	2649	2681	79	109	26	5	16	235	219	251	32
Junior	45	40	3	7	..	14	..	19	24	19	5[a]
Total	3569	3612	112	138	26	22	22	319	298	341	43
Student	139	148	20	59	..	6	..	94	85	94	9

[a] Decrease.

The above table presents a brighter picture than has obtained for several years. The losses of the past four years have been stopped; a net gain of 43 for all classes of membership is reported, which while relatively small, is significant compared to net losses of 164 and 430 for the two preceding years. Resignations and, especially, delinquencies are much fewer in number than a year ago; losses from all sources this year were 298, compared to 438 a year ago. Elections to membership showed a substantial increase over the two preceding years; 319 compared to 254 and 170. Of these, approximately one-third represent renewal or reinstatement of former members, or replacement of memberships resigned.

These are encouraging indications that improvement in business and the lessening of financial stringency is gradually being reflected in an improved membership position for the Society. The membership curve has definitely turned upward again, but there is still much lost ground to be regained. The continued help of the many members who have secured new members, and of such groups as the Special Membership Committee and the several District Committees, which contributed to the good showing of this past year, will be needed in the years ahead as our efforts are intensified to reach the level of membership of pre-depression days. As the Executive Committee has previously pointed out in these annual reports and in the Society *Bulletin*, the source of the strength and virility of the Society lies in its membership, and unquestionably the recovery of memberships temporarily lost during the past three years and the extension of membership into new fields are important problems facing us in these coming years. There is clearly a very general appreciation of this among the members of the Society, and the Executive Committee again bespeaks the earnest support of the membership in this work.

The Society has lost the following members through death:

	DATE OF MEMBERSHIP		DATE OF MEMBERSHIP
Bassett, William H.	1903	Kent, Smith J.	1931
Boyer, Edward D.	1913	Ketchum, Milo S.	1905
Brady, Edward J.	1920	Le Tellier, A. M.	1917
Burr, William H.	1899	Mathews, John A.	1903
Dover, Mary Violette	1926	O'Shaughnessy, M. M.	1916
Doyle, J. S.	1910	Paessler, Robert T.	1916
Dickenson, J. H. S.	1925	Pierce, Dana	1931
Evans, Gwynne	1930	Roe, James P.	1923
Fuller, George W.	1914	Rogers, A. J.	1923
Hammer, Alfred E.	1915	Schlossberg, J. B.	1919
Henry, John A.	1911	Scheldon, Fred C.	1929
Jones, Morgan T.	1911	Tarbox, P. S.	1931
Jupp, Alfred J.	1932	Truesdale, R.	1930

In the death of William H. Bassett on July 21, 1934, only a few weeks after his election to the presidency, the Society lost one of its truly great members, who had served his fellow members in the technical and executive affairs of A.S.T.M. for over thirty years. He was loved and admired throughout the Society and his sudden passing was deeply mourned. A resolution adopted by the Executive Committee was published in the Society *Bulletin* and an engrossed copy was presented to Mrs. Bassett.

Other members distinguished in A.S.T.M. service were among those who passed away, notably Edward D. Boyer and John A. Mathews, both of whom had served as members of the Executive Committee.

Two new sustaining memberships were acquired during the year, namely, The Atlantic Refining Co. and General Motors Corp. This brings the total such memberships to eight, the others being: Bell Telephone Laboratories, Inc.; Socony-Vacuum Oil Co., Inc.; Sun Oil Co.; The Texas Company; Universal Atlas Cement Co.; Western Electric Co., Inc.

The number of student members increased during the year from 139 to 148. The importance of this class of membership is evident and has been emphasized on numerous occasions by the Executive Committee. Establishment of student membership prize awards by Society members continued during the year, new prizes being the following: three at the University of Kansas by Walter Bohnstengel; two at the University of Illinois by S. H. Ingberg; two at the University of Idaho by A. E. Peterson; and two at Iowa State College by H. P. Bigler. Prize awards previously established at Cornell University, Detroit Institute of Technology, Grove

City College, Massachusetts Institute of Technology, Rensselaer Polytechnic Institute, and the University of Pennsylvania, all mentioned in the report a year ago, were renewed during the year. Awards will be made this year in ten scholastic institutions through the interest and generosity of as many members. In the three years in which this plan has been in effect, upwards of 90 student members have been brought into A.S.T.M. in this way. The Executive Committee trusts that this plan may be taken up by other members and these student membership awards extended among many other technical schools. By action of the Executive Committee, students hereafter may secure on their membership any one of the special compilations of A.S.T.M. standards in place of the Student Book of Standards, if desired.

Committee Activities:

As revealed by the program of the present annual meeting, the Society is completing a year of fruitful committee work with respect both to investigations into the properties of materials and the standardization of specifications and methods of test. As usual, the annual reports of two administrative committees, E-9 on Research and E-10 on Standards, supplemented by reviews that will appear in the July and October issues of the *Bulletin*, give a general summary of these activities. Several of the Society's committees have for one reason or another found it difficult or impossible to make progress in their assigned fields during the year.

The Executive Committee, after considering fully the present status of the Society's relationship to the general subject of reinforced concrete, especially to the work of the Joint Committee on Specifications for Concrete and Reinforced Concrete, upon which the A.S.T.M. is represented, decided that there was no longer a logical place for an A.S.T.M. committee on this subject and discontinued Committee C-2 on Reinforced Concrete. The Tentative Rules for Inspection of Concrete and Reinforced Concrete Work (C 44 – 22 T) written by the committee have been referred to the above-mentioned joint committee for recommendation as to their disposition.

Conferences during the year with the various metals committees concerned have indicated that there would be definite advantages in concentrating the Society's work in the development of methods of chemical analysis of both ferrous and non-ferrous metals in a separate standing committee upon which the interested metals committees would be formally represented. It is planned to organize such a standing committee during the present annual meeting, G. E. F. Lundell having been designated as the temporary chairman.

Another new standing committee is being organized during this annual meeting on Gaseous Fuels. A. C. Fieldner has been designated as temporary chairman. The decision to engage in standardization work on gaseous fuels was reached after thorough examination of the field concerned and conferences with various industries and associations whose support and cooperation were desired.

Expansion of the Society's standardization activities in several other directions has been under consideration during the year in the Executive Committee and Committee E-10 on Standards. Among the more important of these are the fields of Paper and Allied Products, and Soap and Other Detergents.

Modifications of Regulations Governing Standing Committees:

A careful review was made during the year of the Regulations Governing Standing Committees[1] in which suggestions for modifications of the Regulations emanating from various sources over the past year or so were considered. The advice of Committee E-10 on Standards and Committee E-5 on Standing Committees was sought, the latter committee being jointly responsible with the Executive Committee for these Regulations.

The following modifications of these Regulations have been approved by the Executive Committee and Committee E-5 and will become effective at the close of this annual meeting:

Section 2.—Change the last sentence of Paragraph (*a*) to read as follows by the omission of the words in brackets:

> Only members of the Society shall be eligible, in general, to appointment on committees, although exceptions may be authorized by the Executive Committee [in favor of representatives of government branches or other societies].

Change the last sentence of Paragraph (*f*) from its present form: namely,

> On such committees either an equal numeric balance shall be maintained between the producers on the one hand and the consumers and general interests, jointly, on the other hand; or the consumers and general interests may be allowed to predominate by majority vote of the producers.

to read as follows:

> Substantial balance with respect to interest shall exist between the general classifications of members appropriate for various types of standards and no one classification shall have a majority save with the recorded assent of the other classifications. In no case shall the number of producers exceed the combined number of consumers and general interests.

Add a footnote to read as follows, to refer to the word "division" which appears in the last sentence of Paragraph (*h*):

> On any letter ballot of the committee where the result of the vote would be affected by the application of this requirement, the Executive Committee has ruled that "a division is demanded" and that hence this provision shall apply.

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[1] 1934 A.S.T.M. *Year Book*, p. 233.

New Section.—Add a new Section 5 covering Supplementary Regulations to read as follows, renumbering the remaining sections accordingly:

5. *Supplementary Regulations Governing Standing Committees.*—The standing committees of the Society shall adopt supplementary regulations governing their various activities, such regulations to cover the following:

Procedure in the nomination and election of officers
Changes in committee personnel
Requirements for quorum
Provisions covering suspension of inactive members
Provisions covering duties and responsibilities of advisory committee, particularly between meetings of the committee
Follow-up on letter ballots
Requirements for membership on subcommittees

NOTE.—Copies of suggested form of regulations may be secured from the Secretary-Treasurer.

Section 7.—At the end of this section add a sentence to read as follows:

Only members of the committee classified thereon as consumers or general interests shall be eligible to hold the office of chairman.

Section 8.—Omit this section which reads as follows, renumbering the remaining sections accordingly:

8. *Resignations.*—Proposed resignations from office or from membership on a standing committee shall be reported directly to the chairman or the secretary of the committee concerned, and the result of any action taken in such matters shall be reported to the Secretary-Treasurer of the Society.

Section 11.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

11. *Tentative Standards.*—The term "Tentative Standards" shall be applied to proposed standards which are published in the Proceedings for one or more years [with a view of eliciting criticism, of which] The committee concerned [will take due cognizance] *shall give due consideration to suggestions and criticisms received* before recommending final action toward their adoption as standard.

Section 14.—Add a footnote to read as follows, to refer to the words "not voting" which appear in the last sentence of the first paragraph:

"Not voting" consists of those returning their ballots so marked.

Add a parenthetical sentence at the end of the second paragraph of this section, to read as follows:

(For regulations governing the method of counting the votes see Section 2 (*h*).)

Section 17.—In the letter ballot form, add a sentence to the introductory paragraph, to read as follows:

The return of this letter ballot is expected even though you are not prepared to vote affirmatively or negatively on all of the items involved.

Section 21.—Substitute for the present Section 21 the requirements for arranging for cooperation between U. S. Government branches and

A.S.T.M. standing committees, which appear at present as an appendix to the Regulations.

Section 26.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 26. *Special Funds.*—[Committees engaged on subjects having a commercial bearing shall be authorized to solicit contributions from manufacturers towards research funds. Contributions from consumers to funds for this and other purposes shall be solicited only by the Executive Committee.] *Committees may be authorized by the Executive Committee to solicit contributions toward funds for research or other purposes.* All funds thus collected *unless otherwise authorized by the Executive Committee* shall be transmitted to the Secretary-Treasurer of the Society and deposited by him in bank and placed to the credit of the committees on the books of the Society, subject to disbursement only on voucher signed by the chairman of the committee concerned.

Section 28.—Change the second sentence to read as follows, by the addition of the italicized words and the omission of those in brackets:

> A standing committee which fails *for three successive years* to present a report [at three successive annual meetings of] *to* the Society will be required to show cause, in a written communication to the Executive Committee, why it should not be discharged.

Section 29.—Add a second paragraph to this section, to read as follows:

> Committees shall forward to the Secretary-Treasurer as early as possible during their preparation draft copies of all proposed methods of testing or specifications containing requirements covering testing apparatus.

Brief comment on certain of these modifications is in order. The modification in Section 2 (*a*) is designed to make possible the appointment of non-members of the Society to membership on standing committees upon the authorization of the Executive Committee whenever this seems desirable. Heretofore membership on standing committees has been limited in general to members of the Society, although some committees have added non-member individuals as adviser members without vote and in certain other instances non-member individuals have been added to the technical or working groups. The change is being made with the thought that the Regulations should be somewhat more flexible in this regard.

The change in Section 2 (*f*) is being made to bring the Society's regulations more nearly into conformity with the American Standards Association procedure with respect to the classification of committees, which is desirable inasmuch as the Society is now acting as sponsor for a considerable number of sectional committees organized under A.S.A. procedure. The modification represents a relatively minor change so far as the Society's practice is concerned with respect to the balance of committee membership; it tends to provide for somewhat greater representation of consumer and general interest groups taken collectively.

Referring to the new Section 5, experience of recent years has indicated the desirability that all standing committees of the Society shall have supplementary regulations governing their various activities, covering various features of organization and operation listed in the proposed new section. Two quite important items that should be covered in such supplementary regulations are requirements for membership on subcommittees and provisions governing suspension of inactive members. It is felt that the definition of "inactive member" should be left to the individual committees; possibly the nearest general criterion would be failure to file letter ballots on questions referred to the membership of the committee. While there is no thought of attempting to mold all the committees of the Society to identical pattern, it is increasingly important that there be a suitable degree of uniformity in the methods of operation of the various standing committees and to that end a suggested form of supplementary regulations has been prepared.

The change in Section 11 is a reflection of a modification made by Committee E-10 on Standards in the note appearing on each tentative standard of the Society, which is intended to give tentative standards a better status by no longer indicating that they are published *only* for the purpose of securing criticisms and suggestions.

In general the remaining modifications and the reasons therefor are obvious. In most instances they have been made to meet certain criticisms that have been received; for example, nowhere do the present regulations provide that the chairman of a standing committee shall be a consumer or general interest, although this has always been intended (Section 7); or they are made in the interest of clarification. Certain footnotes and paragraphs are added that have been previously authorized.

District Committees:

During the year reorganization of the various district committees of the Society was begun, placing the work of these committees upon a more permanent basis, conferring certain authority and responsibilities upon these committees, and giving them a greater degree of autonomy. To this end a Charter for District Committees[1] was adopted by the Executive Committee a year ago, of which the principal features are:

Members are appointed by the Executive Committee for terms of three years, so arranged that the terms of approximately one-third of the membership expire at each annual meeting of the Society. The district committee is to elect its own officers to serve for a term of two years and is given authority to raise funds for support of its activities, such funds to be administered by the committee. Each district committee is required to present annually in October a report of its work to the Executive Committee. The purposes and duties of the district committees are stated in the following words:

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[1] Published in full in the A.S.T.M. *Bulletin*, December, 1934.

> The appointment of a District Committee is intended to provide a means of advancing the interests of the Society in a given locality, and of furthering the purposes for which the Society is organized: namely, "Promotion of Knowledge of Materials of Engineering and Standardization of Specifications and Methods of Testing." To this end the District Committees are given the following authority and responsibilities:
>
> (*a*) To arrange for meetings of members in the District and their guests, at which technical papers may be presented, committee reports, specifications and methods of test of the Society discussed, or other topics within the field of the Society presented for consideration.
>
> (*b*) To sponsor Regional Meetings of the Society, for which arrangements shall be made in conference with the Executive Committee of the Society and the Committee on Papers and Publications.
>
> (*c*) To aid the Executive Committee and the various administrative committees of the Society in such matters as extension of Society membership, promotion of use of A.S.T.M. standards, stimulation of interest in the research and standardization activities of the Society, and procuring of papers for the Annual Meetings of the Society.
>
> (*d*) To arrange, in consultation with the Executive Committee of the Society, for closer participation of the industries of the locality in the research and standardization work of the Society, through representation upon the committees of the Society, and in other ways.
>
> (*e*) To appoint committees of members within the District to study questions concerning specifications and tests for materials that may have special local interest, and to arrange through the Executive Committee for cooperation and contact with local committees of other districts and with the research and standing committees of the Society.

The following district committees have now been reorganized: Pittsburgh District Committee—Dean Harvey, chairman; James Aston, vice-chairman; F. M. Howell, secretary; Cleveland District Committee—H. A. Schwartz, chairman; A. J. Tuscany, secretary; New York District Committee—M. F. Skinker, chairman; W. H. Finkeldey, vice-chairman; L. C. Beard, Jr., secretary; Chicago District Committee—W. A. Straw, chairman; J. de N. Macomb, vice-chairman; G. C. D. Lenth, secretary. The Detroit District Committee was enlarged about a year ago to form a Detroit Committee on Arrangements for the annual meeting and reorganization of the district committee under the new charter has been deferred until after this meeting. The three district committees on the Pacific Coast, namely, Southern California, Northern California and Seattle, have not yet been reorganized.

A Philadelphia District Committee was appointed by the Executive Committee in October, 1934, and was organized in December under the following officers: H. M. Hancock, chairman; Alexander Foster, Jr., vice-chairman; Harold Farmer, secretary. The first activity of the committee was to serve as the local committee on arrangements for the Regional Meeting of the Society held in Philadelphia last March.

The Executive Committee has under consideration the desirability of organizing district committees in other sections of the country, among those being considered are Birmingham, Boston, Kansas City, St. Louis and Washington, D. C.

Meetings and Local Activities:

Since the Thirty-seventh Annual Meeting of the Society last June at Atlantic City, the Sixth Regional Meeting was held in Philadelphia, March 6, 1935. The technical feature was a Symposium on Paint and Paint Materials developed by Committee D-1 on Preservative Coatings for Structural Materials through a special committee headed by R. L. Hallett. About 400 members and visitors attended the two sessions at which the fifteen papers comprising the symposium were presented. The symposium complete with all papers and discussions is being published next month.[1]

The Spring Group Meetings of Committees were held at Philadelphia March 4 to 8, inclusive. Upwards of 135 meetings of main committees, subcommittees and sections were held, and the total registered attendance for the week, 615, exceeded all records for these meetings. Each year this occasion gives indisputable evidence of the earnestness of our committees and their members in attacking the problems assigned to them and in advancing the standardization and research work of the Society.

Two local meetings were held during the year. On March 14 the New York District Committee, with Committee D-9 on Electrical Insulating Materials cooperating, sponsored a meeting at which Prof. Hugh S. Taylor, Head, Department of Chemistry, Princeton University, spoke on "The Chemistry of Deterioration." About 400 members and guests attended. On March 15 a meeting was held under the auspices of the Cleveland District Committee and the Cleveland Purchasing Agents Association at which about 125 members of the two organizations listened to a talk by Vice-President A. C. Fieldner, on "What the A.S.T.M. Can Do for the Purchasing Agent."

Society Meetings in 1936:

The Executive Committee announces that after fully considering various suggestions for a meeting place in 1936, it has been decided to hold the annual meeting of the Society next year at Haddon Hall, Atlantic City, N. J., over the dates June 29–July 3.

It is also announced that the Seventh Regional Meeting of the Society will be held in Pittsburgh on March 4, 1936, under the auspices of the Pittsburgh District Committee. The topic selected for the technical sessions is "Metals of High Strength-Weight Ratio for Structural Purposes." A program committee is being formed by the district committee with the cooperation of certain interested standing committees, which will be responsible for the solicitation and editing of papers for the symposium. The Spring Group Meetings of committees will be held at the same time in Pittsburgh over the dates March 2 to 6, inclusive.

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[1] Available as a separate publication, Symposium on Paint and Paint Materials, Philadelphia Regional Meeting, Am. Soc. Testing Mats. (1935).

Third Exhibit of Testing Apparatus and Related Equipment:

As announced in recent issues of the Society *Bulletin*, the third Exhibit of Testing Apparatus and Related Equipment is being held in conjunction with this annual meeting. Experience in the first two exhibits in 1931 and 1933 has fully justified the policies that have governed these exhibits. The plan of exhibiting commercial apparatus of manufacturers and distributors, and non-commercial apparatus developed in research, government and university laboratories, supplemented by exhibits illustrative of the activities of some of the committees of the Society, has provided the scientific and educational atmosphere designed to make these exhibits an integral feature of the annual meetings and of real interest to our members and committees. There have been many interesting developments in testing apparatus and equipment during the past two years; improved business conditions have made possible an exhibit considerably larger than that in 1933, and members will certainly find it to their interest and advantage thoroughly to review this year's exhibit. Attention is particularly called to the striking exhibits sponsored by committees of the Society, which have been made possible by hard and earnest work on the part of committee members who shouldered the responsibilities of collecting and placing these exhibits.

Publications:

The past year has been an exceptionally busy and active one with respect to Society publications. The following regular publications were issued and distributed to the members: *Proceedings*, including preprints of reports and papers; the 1934 Supplement to the Book of A.S.T.M. Standards; the Index to A.S.T.M. Standards and Tentative Standards; and the Year Book. Six issues of the A.S.T.M. *Bulletin* were published. The report on Significance of Tests of Concrete and Reinforced Concrete sponsored by Committee C-9 on Concrete and Concrete Aggregates and presented at the annual meeting in 1933 was published and distributed to all members who had requested copies. The Book of A.S.T.M. Tentative Standards and the Symposium on the Outdoor Weathering of Metals and Metallic Coatings, containing the papers and discussions at the Washington Regional Meeting in March, 1934, were published and furnished to members on order. A comparative statement of the volume of these publications for the past four years follows:

	1931, PAGES	1932, PAGES	1933, PAGES	1934, PAGES
Proceedings	2416	1895	1914	2288
Book of A.S.T.M. Standards	....	....	2348	....
Supplement to Book of A.S.T.M. Standards	144	102	....	224
Index to A.S.T.M. Standards and Tentative Standards	103	119	124	142
Year Book	342	....	248	251
Supplement to Year Book	....	133	....	....
Book of A.S.T.M. Tentative Standards	1008	1236	1164	1288
Regional Meeting Symposium	152	159	121	119
Joint A.S.M.E.-A.S.T.M. Symposium on Effect of Temperature on the Properties of Metals	829	....	....	....
Report on Significance of Tests of Concrete and Concrete Aggregates	....	....	....	127
	4724	3644	5919	4439

During the past year, the Society published the following compilations of Standards:

A.S.T.M. Standards on Petroleum Products and Lubricants (Committee D-2), 346 pages, 3500 copies, published annually.

A.S.T.M. Standards on Electrical Insulating Materials (Committee D-9), 288 pages, 750 copies, published annually.

A.S.T.M. Standards on Coal and Coke (Committee D-5), 112 pages, 2000 copies. This is a new publication and is being published tentatively on a biennial basis.

A.S.T.M. Standards on Refractory Materials (Committee C-8), 148 pages, 2500 copies, published biennially.

There are two other compilations in this series which were published in 1933 and will be republished in revised form this fall, the one covering A.S.T.M. Standards on Preservative Coatings for Structural Materials (Committee D-1) and the other A.S.T.M. Standards on Textile Materials (Committee D-13). These several compilations of standards have proved beyond doubt to be an important means of making A.S.T.M. standards readily and conveniently available to the industries that produce and use these materials, and committees of the Society have been invited to prepare such compilations whenever they believe that publication of their standards in this way will meet with favor and support. Such compilations are being considered at the present time with respect to the fields of rubber products and bituminous materials. In addition, the attention of the standing committees has also been called to the importance of reports by the committees on the significance and application of the testing methods they have developed. Two excellent reports on the subject have been prepared by Committees C-9 on Concrete and Concrete Aggregates and D-2 on Petroleum Products and Lubricants.

The pamphlet "Selected A.S.T.M. Standards for Students in Engineering," 216 pages, was reprinted for a fourth edition of 4000 copies. This pamphlet is sold to many technical schools, for which a special student price of fifty cents is fixed, and it is also given to student members on their dues.

Other reprints and special publications printed last year include the following:

Significance of Tests of Petroleum Products and Lubricants, revised edition, 80 pages, 6000 copies.

Service Characteristics of Light Metals and Alloys, reprinted from 1934 report of Committee B-7 on Light Metals and Alloys, Cast and Wrought, 37 pages, 2000 copies.

Quality Standards for Wrought Iron, reprinted from the 1934 report of Committee A-2 on Wrought Iron, 18 pages, 2500 copies.

Impact Testing of Cast Iron, reprinted from the 1933 report of Committee A-3 on Cast Iron, 51 pages, 750 copies.

Manual on Presentation of Data, 45 pages, second printing 1500 copies.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, 24 pages, 750 copies.

Report of Committee A-5 on Corrosion of Iron and Steel, 32 pages, 3 insert plates, 1000 copies.

Two years ago the Executive Committee announced the adoptio a policy of gradually expanding the Society *Bulletin* as finances permit to provide a still better and more frequent means of contact between the Society and its members. It was pointed out that there is much material of current interest that might advantageously be published in an enlarged *Bulletin*, such as "general information" papers, papers of general value relating to standards and research, and interim and progress reports of committees. Specifications and methods, suggested test procedures, etc., which committees desire to publish as information might perhaps more suitably be published in the *Bulletin* than in the *Proceedings*. In view of curtailment of Society income during the past two years and the necessity of providing first for the publication of standards and tentative standards, committee reports and technical papers, there have not been sufficient funds available to permit this expansion of the *Bulletin* on the scale desired. A start in this direction, however, was made during the past year. The December, 1934, *Bulletin* carried a paper on the subject "Cylinder *versus* Cube *versus* Prism as the Compression Test Specimen for Mortars" and the January, 1935, issue contained proposed Specifications for Lead-Coated Copper Sheets prepared by Committee B-2 on Non-Ferrous Metals and Alloys. These are the first documents of their kind to appear in the *Bulletin* and are typical of the kind of material that will be included more frequently as funds permit. Beginning with the December issue of the *Bulletin* there has appeared a series of sketches about members affiliated with the Society for twenty-five years or more who have been prominent and active in its committee work.

With the steady increase in the number of standards adopted by the

Society and the consequent growth in the size of the two volumes of the Book of Standards, it will eventually become impracticable to continue their publication in the present form. The Committee on Papers and Publications has been asked by the Executive Committee to make a thorough study of the situation and to submit a report and recommendations in time for consideration prior to the publication of the next edition of the Book of Standards in 1936.

Finances:

Report for the Fiscal Year 1934.—The annual statement of the finances of the Society follows in the report of the auditors for the fiscal year, January 1 to December 31, 1934.

Total receipts from dues and entrance fees for 1934 were $67,467.38, an increase of approximately $2000 over corresponding receipts for 1933. Receipts from sales of publications were the largest in the Society's history, $40,744.69, including the large volume of sales of the Book of Standards following its publication late in 1933. Receipts from sales of special reports, including the special compilations of A.S.T.M. Standards, symposiums, reports on significance of tests, etc., totalling $14,631.40, were likewise larger than in any previous year. These facts are significant, inasmuch as the steadily increasing sales of publications throughout the industrial depression, stimulated greatly by the sales promotion work undertaken in recent years, have partially offset loss of income from membership dues and thereby in part made it possible for the Society to carry on its work throughout a difficult period without curtailment in any essential things. Total operating receipts (budgeted) were $116,808.21. Total operating disbursements (with all current bills paid) were $112,717.00, or about $4100 within receipts.

In line with policy since membership losses began, the surpluses from yearly operations have not been added to "permanent" reserve but have been set aside as an emergency fund. So far it has not been necessary to touch this surplus, which including that from 1934 operations now amounts to about $12,500. Of this amount the sum of $4800 has been earmarked for addition to the principal of the A.S.T.M. Research Fund; the remainder, $7700, is still held as a contingency reserve.

The report of the auditors gives the balance sheet of assets and liabilities, including special and designated funds (that is, Research Fund, Medal and Lecture Fund and Committee Funds); statement of receipts and disbursements, in which items are classified into "operating" (budget) and "non-operating"; details of special funds; investments of Society and special funds, both book and market values being given; and a comparison of the financial condition of the Society at the close of the past five years. The Headquarters Fund now comprises $1041.56, after payment out of

REPORT OF THE AUDITORS FOR THE FISCAL YEAR, JANUARY 1, 1934, TO DECEMBER 31, 1934

PHILADELPHIA, January 9, 1935

MR. C. L. WARWICK, *Secretary-Treasurer*
AMERICAN SOCIETY FOR TESTING MATERIALS
Philadelphia, Pa.

Dear Sir:

We have examined the books and accounts of your Society for the year ended December 31, 1934. The books and accounts examined were found correct and in satisfactory condition.

We have prepared the annexed Balance Sheet as of December 31, 1934, and Statement of Cash Receipts and Disbursements for the twelve months ended that date, together with other supporting schedules. The schedules are in agreement with the records of your Society.

Investments owned were verified by actual inspection and count and found to be intact and in agreement with the schedule of securities owned as detailed herewith. We verified the collection of interest on investments owned for the year 1934 and found it fully accounted for, except interest on $6000 Missouri Pacific Railroad First and Refunding Mortgage 5's 1977 which defaulted in their interest payments September 1, 1933.

Respectfully submitted,
(Signed) JOHN HEINS AND CO.

BALANCE SHEET AS OF DECEMBER 31, 1934

(Including Special and Designated Funds)

ASSETS

General Funds:				
Current: Cash	$17 542.12			
Less checks drawn as of December 31, 1934—Cost of *Proceedings* in hands of Secretary-Treasurer that date	13 750.00			
		$3 792.12		
Investments (Market Value, $29,555.00)—Cost		38 924.05		
Accounts Receivable		7 315.19		
Total Current Assets—General Funds			$50 031.36	
Furniture and Fixtures			8 010.84	
A.S.T.M.-A.S.M.E. Symposium on Effect of Temperature: Special Account for Financing Book			2 431.60	
Claim Against Closed Bank			20.56	
Total General Funds				$60 494.36
Special and Designated Funds:				
Cash: A.S.T.M. Research Fund		$1 626.13		
Dudley Medal and Marburg Lecture Fund		566.69		
Committee Funds		12 116.49		
			$14 309.31	
Investments:				
A.S.T.M. Research Fund (Market Value, $6,030.00)—Cost		$8 141.75		
Dudley Medal and Marburg Lecture Fund (Market Value, $4,770.00)—Cost		6 625.00		
Committee Funds (Market Value, $6,223.12)—Cost		$6 119.92		
			20 886.67	
Total Special and Designated Funds				35 195.98
Total Assets				$95 690.34

LIABILITIES

General Funds:			
Current: Accounts Payable—			
Committee A-1	$190.00		
Committee C-1	447.48		
International Association for Testing Materials	29.35		
Advance Collections	1 538.16		
Total Current Liabilities—General Funds		$2 204.99	
Life Membership Fund	$3 005.20		
Headquarters Fund	1 041.56		
Publication Fund	3 015.00		
Book of Standards Reserve	5 023.44		
Surplus	46 204.17		
		58 289.37	
Total General Funds			$60 494.36
Special and Designated Funds:			
A.S.T.M. Research Fund		$9 767.88	
Dudley Medal and Marburg Lecture Fund		7 191.69	
Committee Funds		18 236.41	
Total Special and Designated Funds			35 195.98
Total Liabilities and Funds			$95 690.34

COMPARISON OF GENERAL FUNDS FOR FISCAL YEARS 1930–1934, INCLUSIVE

At Close of Fiscal Year	Assets				Liabilities			
	Cash	Investments[a]	Accounts Receivable and Miscellaneous	Furniture and Fixtures	Accounts Payable and Miscellaneous	Reserve for Book of Standards	Miscellaneous Funds[a]	Surplus
1930	$4 567.78	$44 255.51	$10 873.38	$6 209.36	$2 935.58	....	$20 438.05	$42 532.40
1931	6 414.07	49 946.21	12 668.06	6 571.94	3 905.00	5 690.70	19 438.05	46 566.53
1932	5 945.05	49 035.80	14 834.01	6 301.67	2 077.61	11 743.20	19 229.55	43 066.17
1933	7 869.45	38 266.50	16 739.78	6 092.51	3 178.98	....	19 008.68	46 780.58
1934	3 792.12	38 924.05	9 767.35	8 010.84	2 204.99	5 023.44	7 061.76	46 204.17

[a] The funds reported in this column for 1930 to 1933, inclusive, include the principal of the A.S.T.M. Research Fund, which beginning with 1934 is no longer included under "General Funds."

RECEIPTS AND DISBURSEMENTS

FOR THE PERIOD JANUARY 1, 1934, TO DECEMBER 31, 1934

Cash balance January 1, 1934 (without inclusion of Investments of General Fund carried as cash and estimated cost of 1933 Proceedings)	$2 208.90	
Less, cash in A.S.T.M. Research Fund	1 338.67	
Cash balance		$870.23

RECEIPTS

Operating Receipts (Budgeted):			
Dues and Entrance Fees:			
Current Dues	$62 343.65		
Past Dues	2 127.71		
Advance Dues	1 053.02		
Income, Life Membership Fund	150.00		
Entrance Fees	1 793.00		
Total Dues		$67 467.38	
Sale of Publications:			
Separate Standards	$4 004.33		
Book of Standards	11 947.39		
Book of Standards (Members, both parts)	378.00		
Book of Tentative Standards	6 111.32		
Proceedings	3 081.65		
Selected Standards for Students	590.60		
Special Reprints and Miscellaneous	14 631.40		
Total Sale of Publications		40 744.69	
Miscellaneous:			
Binding (Members)	$411.50		
Advertising, Bulletin	2 728.90		
Advertising, Index (1933 edition)	373.00		
Authors' Reprints	235.17		
Sale of Certificates of Membership	47.50		
Interest on Deposits and Investments	2 603.82		
Income, A.S.T.M. Research Fund	387.50		
Registration and Other Fees, Annual Meeting	919.00		
Committee A-1 for Technical Assistant	700.00		
Miscellaneous	189.75		
Total Miscellaneous Items		8 596.14	
Total Operating Receipts (Budgeted)		$116 808.21	
Non-Operating Receipts (Not Budgeted):			
Investments, Matured or Sold	$12 315.62		
Excess Remittances	122.05		
Accrued Interest	26.44		
Seaview Golf Club (see disbursements)	25.00		
International Association for Testing Materials, Dues	529.50		
Symposium on Effect of Temperature	337.90		
Committee C-1 for Technical Assistant	1 500.00		
A.F.A. Share, Cast Iron Symposium	403.82		
Miscellaneous	37.60		
Total Non-Operating Receipts		15 297.93	
Total Receipts			**132 106.14**
Carried forward			**$132 976.37**

Brought forward			$132 976.37

DISBURSEMENTS

Operating Disbursements (*Budgeted*):

Publications:			
Year Book	$1 943.95		
Book of Standards	264.74		
Book of Standards Supplement	1 980.29		
Book of Tentative Standards	3 420.42		
Selected Standards for Students	869.50		
Proceedings	20 251.21[a]		
Preprints	2 285.84		
Regional Meeting Papers	527.77		
Bulletin and Circular to Members	3 759.24		
Separate Standards	1 818.35		
Index to Standards and Tentative Standards	86.04		
Reprints (Reports, Papers, Symposiums, etc.)	6 026.25		
Miscellaneous Printing (Authors' Reprints, etc.)	479.78		
Total Disbursements, Publications		$43 713.38	
Investments (out of current income toward cost of 1936 Book of Standards)		5 023.44	
Salaries		42 172.30	
General Office Expenses		10 065.02	
Expenses, Standing Committees		2 736.76	
Expenses, Meetings		1 564.38	
Traveling Expenses, Administrative and Special Committees		1 765.09	
American Standards Assn. and Sectional Committees		1 250.00	
Rent, Headquarters		3 200.00	
Furniture and Fixtures		643.32	
Certificates of Membership		36.50	
Income A.S.T.M. Research Fund		387.50	
Central Lumber Standards Committee		25.00	
Inter-Society Color Council		25.00	
Miscellaneous		109.31	
Total Operating Disbursements (Budgeted)		$112 717.00	

Non-Operating Disbursements (*Not Budgeted*):

Balance on cost of 1933 Proceedings	$10 200.00[b]		
Accrued Interest	26.44		
Refund of Excess Remittances	122.05		
Seaview Golf Club (see receipts)	25.00		
International Assn. for Testing Materials	517.00		
Symposium on Effect of Temperature	17.11		
Technical Assistant, Committee C-1	1 388.26		
A.F.A. Share, Cast Iron Symposium	403.82		
New Headquarters	3 767.57		
Total Non-Operating Disbursements		16 467.25	
Total Disbursements			$129 184.25
Cash Balance December 31, 1934			$3 792.12

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[a] This amount includes $13,750.00 in the form of checks drawn against cost of *Proceedings*, but not actually paid on December 31, 1934, pending final completion of the publication work.

[b] See Annual Report for 1933. This sum is reported as disbursement out of 1933 income. The checks were in effect drawn against the investments carried as cash but were not actually paid out until early in 1934.

In addition to the general funds of the Society, the Secretary-Treasurer has on hand the following funds:

A.S.T.M. Research Fund

Balance, January 1, 1934:				
Principal:				
Investments (At Cost)	$8 141.75			
Cash	37.60			
		$8 179.35		
Income—Cash		1 301.07		
			$9 480.42	
Receipts				
Interest on Deposits and Investments			387.50	
				$9 867.92
Disbursements				
Contribution to Committee B-6			$100.00	
Tax on Checks			.04	
				100.04
Balance, December 31, 1934:				
Principal:				
Investments (At Cost)		$8 141.75		
Cash		37.60		
			$8 179.35	
Income—Cash			1 588.53	
				$9 767.88

Dudley Medal and Marburg Lecture Fund

Balance, January 1, 1934:			
Principal—Investments (At Cost)	$6 625.00		
Income—Cash	556.02		
		$7 181.02	
Receipts			
Interest on Deposits and Investments		330.00	
			$7 511.02
Disbursements			
Honorarium, 1934 Lecturer		$200.00	
Cost of 1934 Medal		80.00	
Engrossing 1934 Lecture Certificate		3.25	
Miscellaneous		36.00	
Tax on Checks		.08	
			319.33
Balance, December 31, 1934:			
Principal—Investments (At Cost)		$6 625.00	
Income—Cash		566.69	
			$7 191.69

Committee Funds

Committee A-1 on Steel	$717.58	
Committee A-3 on Cast Iron	30.84	
Committee A-5 on Corrosion of Iron and Steel	6 868.77	
Committee A-5, Subcommittee X on Embrittlement Investigation	129.54	
Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys	3 436.64	
Committee B-6 on Die-Cast Metals and Alloys	338.41	
Committee C-1 on Cement	948.62	
Committee C-1, Cement Reference Laboratory	363.73	
Committee C-9 on Concrete and Concrete Aggregates	629.47	
Committee C-10 on Hollow Masonry Building Units	254.93	
Committee C-18 on Natural Building Stones	.01	
Committee D-1 on Preservative Coatings for Structural Materials	33.49	
Committee D-14 on Screen Wire Cloth	13.97	
Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel	357.21	
A.S.A. Sectional Committee on Specifications for Cast-Iron Pipe and Special Castings	3 033.66	
A.S.A. Sectional Committee on Classification of Coals	1 079.54	
Total Committee Funds		$18 236.41
Accounted for as follows:		
Investments (At Cost)	$6 119.92	
Cash Balance, December 31, 1934	12 116.49	
		$18 236.41

INVESTMENTS, DECEMBER 31, 1934

		Book Value	*Market Value*
Society Funds:			
$2 000	Penna. R. R. Bonds, Seconds, 5's due 1964	$2 000.00	$2 120.00
6 000	Southeastern Power & Light Co. Debenture Bonds, 6's, Series A, due 2025	6 240.00	3 900.00
7 000	Baltimore & Ohio R. R. General and Refunding Bonds, 5's, due 1995	7 087.50	5 092.50
9 000	Baltimore & Ohio R. R. General and Refunding Bonds, 5's, Series F, due 1996	9 106.55	6 435.00
6 000	Missouri Pacific R. R. First and Refunding Mortgage Bonds, 5's, Series F, due 1977 (Defaulted September 1, 1933)	5 690.70	1 545.00
10 000	New York Central R. R. Refunding and Improvement Bonds, 5's, due 2013	5 108.55	6 600.00
3 000	American Telephone and Telegraph Co. S. F. Debenture Bonds, 5's, due 1960	3 159.75	3 337.50
500	Consolidated Gas Co. of New York Bonds, 5½'s, due 1945	531.00	525.00
$43 500		$38 924.05	$29 555.00
A.S.T.M. Research Fund:			
$3 000	Baltimore & Ohio R. R. General and Refunding Bonds, 5's, due 1995	$3 037.50	$2 182.50
1 500	Baltimore & Ohio R. R. General and Refunding Bonds, 5's, Series F, due 1996	1 511.25	1 072.50
1 500	Consolidated Gas Co. of New York Bonds, 5½'s, due 1945	1 593.00	1 575.00
2 000	First Mortgage Real Estate Bonds on 1317 Spruce St., Philadelphia, 6's, due 1945	2 000.00	1 200.00
$8 000		$8 141.75	$6 030.00
Dudley Medal and Marburg Lecture Fund:			
$500	Baltimore & Ohio R. R. General and Refunding Bonds, 6's, due 1995	$550.00	$405.00
6 000	Baltimore & Ohio R. R. General and Refunding Bonds, 5's, due 1995	6 075.00	4 365.00
$6 500		$6 625.00	$4 770.00
Committee Funds:			
$6 000	U. S. Liberty Bonds, 4th issue 4¼'s, due 1938: Committee A-5 .... $5 610.39 Committee C-1 .... 509.53	$6 119.92	$6 223.12
$64 000		$59 810.72	$46 578.12

Market Values, except on First Mortgage Real Estate Bonds on 1317 Spruce St., Philadelphia, on which there was no quotation, have been taken from the *Philadelphia Inquirer*, as of January 2, 1935, or the *Commercial and Financial Chronicle* of January 5, 1935.

the Fund of the entire cost ($3988.44) of the establishment of the new Society Headquarters.[1] Furniture and fixtures, valued at $8010.84 in the statement of assets, includes all new furnishings for the headquarters. When the latter were purchased (at a total cost of $3557.39), the value on the books of furniture and fixtures moved from the old to the new Society rooms was $6092.51, based upon annual depreciation of 10 per cent of the annual balance. It was decided that a rate of 12½ per cent annual depreciation should be applied hereafter to this item and at the same time the value of older furnishings was arbitrarily reduced to a sum equivalent to the 12½ per cent depreciation rate.

No account has been taken in the accompanying financial statement of the assets of the Society in the form of publications in stock, with the exception of the cost value, $2431.60, of the copies still in stock of the Joint A.S.M.E.-A.S.T.M. Symposium on Effect of Temperature on the Properties of Metals purchased by the Society from the joint account described in a previous report;[2] this amount is included in the statement of assets. The inventory of technical publications on June 1, 1935, may be summarized approximately as follows:

		NUMBER OF COPIES
Year Book		355
Proceedings		5 360
Index to Proceedings, 4 parts, each		300
Book of A.S.T.M. Standards	Part I, Metals	2 140
	Part II, Non-Metals	2 176
1934 Supplement to Book of Standards		2 778
Book of A.S.T.M. Tentative Standards		287
Index to Standards and Tentative Standards		1 500
Selected Standards for Students in Engineering		2 980
Reprints of 493 Standards (approximate)		30 000
Symposium on Effect of Temperature on the Properties of Metals		727
Special Reprints (approximate)		24 000

1935 Finances.—In budgeting Society operations for 1935, the Executive Committee was again faced with considerable uncertainty regarding probable income, although for the first time in several years it has been possible to anticipate a net increase in membership. Accordingly the budget of receipts and disbursements was set up on a tentative basis subject to review and to adjustment of disbursements within actual income, supplemented by such reserve funds as it was felt might be appropriately used if required. Receipts from dues and entrance fees have been estimated at $68,350, approximately $1000 greater than 1934 receipts. Receipts from sales of publications were estimated at $29,000, considerably less than for

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[1] See *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 53 (1934); of the total cost, $3767.57 was paid in 1934, as noted in the current report of the auditors.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 53 (1932).

1934 which as previously noted included the heavy sales of the 1933 Book of Standards. Miscellaneous receipts, including interest on investments, advertising in the *Bulletin* and Index to Standards, and income from the Third Exhibit, were estimated at $12,150, bringing the total of estimated current receipts to $109,500. Experience of the first five months has been definitely encouraging with respect to income from dues and publications sales and the prospects are that current income will be considerably above the estimate. The budget of disbursements provides for the usual publications, for which unit costs are expected to be at the approximate level of 1934 costs. Full provision has been made for publication of standards, tentative standards and committee reports, but some curtailment is still necessary respecting technical papers and discussions and in the volume of preprinting. The Executive Committee will review the entire budget during the annual meeting, at which time income for the year can be predicted with greater certainty and any necessary adjustments in expenditures determined.

Headquarters:

The Society has now occupied its new headquarters[1] for about a year and a half. In every way they have proved suitable, and have contributed greatly to more effective and efficient functioning of the Society staff. Many members have visited the Society's rooms during the year, and a number of committee meetings and conferences have been held there. It is clear that the acquiring of these new quarters has been an excellent move.

Inter-Society and Other Cooperative Relations:

The Society's activities have always and of necessity involved cooperative relationships with many other organizations, which proceed along well-established lines. During the year news items in the *Bulletin* have told of some of the activities in this direction and these hardly require mention here. There are, however, several happenings during the year that merit specific mention in this report.

Respecting American Standards Association matters, the Standards Council has approved a plan of organization of its work that contemplates the formation of "divisional committees" covering the various industries. Such a "departmentalization" of A.S.A. activities seems essential in view of the increasing diversity and extent of the national standardization movement. One such committee has recently been authorized, namely, a Building Code Correlating Committee, which is to function as a representative planning and correlating agency, advisory to the American Standards Association, in matters concerning development and harmonizing of building codes. This has come about through the discontinuance of the former building code committee of the Department of Commerce and the request of the latter that the Department and the A.S.A. cooperate in the future development of building code recommendations.

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[1] The headquarters were described in the report a year ago (*Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 53 (1934) and in the Society *Bulletin*.

The Standards Council has approved a proposal, referred to in the report of the Executive Committee last year, that the Society organize under its sponsorship a Sectional Committee on Petroleum Products and Lubricants. Invitations have been extended to thirty national organizations, including certain federal departments, to accept membership on this committee and to appoint official representatives. It is planned to effect formal organization as soon as the personnel of the committee is completed.

Mr. F. M. Farmer has been reappointed as the Society's representative on the A.S.A. Standards Council for the term of three years ending December 31, 1937.

The Society has formed with the Society of Automotive Engineers a joint conference committee to consider projects and questions relating to the research activities of the two societies in petroleum products. The members of the conference committee are: Representing S.A.E., Messrs. B. B. Bachman, A. L. Beale and T. C. Smith, with C. B. Veal *ex-officio;* representing A.S.T.M., Messrs. R. P. Anderson, T. A. Boyd and T. G. Delbridge, with C. L. Warwick *ex-officio*.

The importance of fullest possible coordination of A.S.T.M. work with the railroads as organized through the American Railway Engineering Association and the American Railroad Association (now the Association of American Railroads) has always been recognized and cooperative relations involving a number of A.S.T.M. committees have long been established. An important step in advancing these cooperative relationships was taken when a meeting was held on May 6, 1935, attended by the Standardization Committee of the A.R.E.A., Committee E-10 on Standards of this Society and the chairmen of nine A.S.T.M. committees whose activities are of immediate interest to A.R.E.A. The primary purpose was an interchange of information about the standardization activities of the two societies, in connection with which there was prepared a comprehensive analysis of A.R.E.A. standardization activities and their relationship to corresponding A.S.T.M. specification work. It is the mutual desire of the standardization committees of both organizations that there be official representation of A.R.E.A. on all A.S.T.M. committees dealing with materials considered by A.R.E.A. in its own extensive committee work, and steps to this end are being considered by the executive officers of the two bodies.

In view of the increasing extent to which the Society is necessarily concerned with the work of various joint and sectional committees, and the growing number of A.S.T.M. representatives upon such committees (upwards of 45 at present), the Executive Committee has established the procedure of calling for annual reports from all such representatives which will be reviewed by Committee E-10 on Standards. A statement of the responsibilities of A.S.T.M. representatives upon joint and sectional committees and upon committees of other societies has also been prepared.

The Executive Committee reported a year ago[1] on the contacts that had been made with and the offers of assistance respecting materials standards made to the Public Works and National Recovery Administrations, and also to the various Code Authorities under the N.R.A. in those industries presumably concerned with the fields of work covered by A.S.T.M. Similar contacts were made in the summer of 1934 with the newly organized Federal Housing Administration; complete sets of A.S.T.M. standards and tentative standards were furnished to that Administration and assurance was given of the Society's desire to assist in so far as possible in those phases of the housing program that involved the utilization of standard tests and specifications for materials.

Respectfully submitted on behalf of the Executive Committee,

HERMANN VON SCHRENK,
President.

C. L. WARWICK,
Secretary-Treasurer.

June, 1935.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 58 (1934).

REPORT OF COMMITTEE A-1

ON

STEEL

During the past year, Committee A-1 on Steel has held two series of meetings: the first at Atlantic City, N. J., June 25 and 26, 1934; and the second at Philadelphia, Pa., March 4 to 6, 1935. Important progress was made in committee work at these well-attended meetings.

Since the 1934 annual meeting, 12 new members have been elected and 2 resignations accepted, the committee membership now totaling 206, of whom 92 are classified as producers and 114 as non-producers; of the latter, 86 are consumer and 28 general interest members.

Tentative Standards and Revisions Approved During the Past Year:

Two proposed tentative standards were submitted to the Society through Committee E-10 on Standards[1] and were accepted for publication as tentative on August 22, 1934. These specifications cover Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 34 T) and Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 34 T) and appear in the 1934 *Proceedings*.[2] There were also submitted to Committee E-10[1] a number of revisions in the following specifications:

- Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 33 T)
- Standard Specifications for Structural Steel for Ships (A 131 – 33)
- Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 33)
- Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 33)
- Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33)
- Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 33)

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee A-1 reported th following results of the letter ballot vote of a total of 86 ballots returned from a committee membership of 19 Tentative Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatur from 750 to 1100 F. (A 157 – 34 T), 51 affirmative, none negative, and 35 ballots marked "not voting"; Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 34 T), 50 affirmative, 1 negative, and 35 ballots marked "not voting"; Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 33 T), 51 affirmative, 1 negativ and 34 ballots marked "not voting"; Tentative Revisions of Standard Specifications for Structural Steel for Ships (A 131 – 33), 56 to 58 affirmative, none negative, and 28 to 30 ballots marked "not voting" (the range in votes being due to the recording of votes separately on each of the revisions recommended); Tentativ Revision of Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 33), 56 affirmative, 2 negativ and 28 ballots marked "not voting"; Tentative Revision of the three Standard Specifications for Steel for High-Temperature Service, 50 affirmative, none negative, and 36 ballots marked "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 609 and 617, respectively (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 67 and 75, respectively.

Revisions of the tentative specifications were approved and the changes in the standards were accepted for publication as tentative. The revised tentative specifications and the tentative revisions appear in the 1934 *Proceedings*.[1]

Approval of Specifications by American Standards Association:

During the year, three specifications under the jurisdiction of Committee A-1 have been approved as American Standard by the American Standards Association, as follows:

Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 33) (A.S.A. No.: G17.1 – 1934)
Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33) (A.S.A. No.: G17.2 – 1934)
Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 33) (A.S.A. No.: G17.3 – 1934)

The following specifications are being considered by the committee for submission to the A.S.A. for approval:

Standard Specifications for Steel for Bridges (A 7 – 34)
Standard Specifications for Steel for Buildings (A 9 – 34)
Standard Specifications for Mild Steel Plates (A 10 – 34)
Standard Specifications for Structural Steel for Locomotives and Cars (A 113 – 33)
Standard Specifications for Structural Rivet Steel (A 141 – 33)
Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 33) as revised
Standard Specifications for Rail-Steel Concrete Reinforcement Bars (A 16 – 33) as revised
Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (A 82 – 34)

RECOMMENDATIONS AFFECTING STANDARDS

The recommendations of the committee affecting its standard and tentative specifications are listed first in summarized form for convenience together with an analysis of the letter ballot on each item. Where necessary, these recommendations are referred to further, being grouped for convenience in the order of the subcommittees responsible for them.

I. Proposed Tentative Standards.—Two proposed Tentative Specifications for Axle-Steel Concrete Reinforcement Bars, and for Seamless Low-Carbon-Steel Still Tubes for Refinery Service are recommended for publication as tentative, as appended hereto.[2]

II. Proposed Revisions of Standards.—The committee recommends that revisions, as appended hereto,[3] of the six standard specifications listed below be published as tentative for one year before referring them to letter ballot of the Society for adoption as standard:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1254 to 1258 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 1182 to 1186.
[2] See pp. 552 and 590.—ED.
[3] See p. 1371.—ED.

- Standard Specifications for Open-Hearth Carbon-Steel Rails (A 1 - 30)
- Standard Specifications for Quenched High-Carbon-Steel Splice Bars (A 49 - 21)
- Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A 68 - 27)
- Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 34)
- Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 - 33)
- Standard Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 - 33)

III. Proposed Revision of Tentative Standard.—Revisions are recommended, as appended hereto,[1] in the Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 - 34 T), the revised specifications to be continued as tentative.

IV. Adoption of Tentative Standard as Standard.—The committee recommends that the Tentative Specifications for Heat-Treated Steel Elliptical Springs (A 147 - 33 T)[2] be referred to letter ballot of the Society for adoption as standard, without revision.

V. Adoption of Tentative Revisions of Standards as Standard.—The committee recommends that the tentative revisions proposed last year in the following standards be submitted to the Society for adoption as standard:

- Revision of Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 - 33)[3]
- Revision of Standard Specifications for Rail-Steel Concrete Reinforcement Bars (A 16 - 33)[3]

VI. Withdrawal of Tentative Standard.—The immediate withdrawal of the Tentative Specifications for Carbon-Steel Castings for Industrial, Railroad and Marine Uses (A 154 - 33 T)[4] is recommended. When these specifications were developed, the desirability of a consolidated specification, to cover in one document requirements for castings used in the industrial, railroad and marine fields, was thought to be a move in the right direction. Recently, however, a number of matters have developed which it has been difficult to cover adequately in revisions of the consolidated specification. After careful consideration by Subcommittee VIII on Steel Castings (W. C. Hamilton, chairman), the immediate withdrawal of Tentative Specifications A 154 is proposed. Concurrent with this action, Subcommittee VIII appointed a new subgroup, under the chairmanship of R. A.

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[1] See p. 69.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 564 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 45.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1255 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1183.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 544 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 19.

Bull, to prepare requirements covering separately the different classes of carbon-steel castings. This work is actively under way and it is the hope of the committee, that in the near future, at least new tentative specifications covering railroad castings will be submitted.[1]

VII. List of Specifications for Steel Suitable for Fusion Welding (A 151 – 33).—The committee recommends that the titles of the following three specifications be included immediately in the List of Specifications for Steel Suitable for Fusion Welding (A 151 – 33).[2] It accordingly asks for the necessary nine-tenths vote at the annual meeting in order that this revision may be submitted to letter ballot of the Society:

Standard Specifications for Mild Steel Plates (A 10 – 34)[3]
Tentative Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 33 T)[4]
Tentative Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates Over 2 in. up to and Including 4 in. in Thickness) (A 150 – 33 T)[4]

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Specifications for Axle-Steel Concrete Reinforcement Bars	61	1	70
Specifications for Seamless Low-Carbon-Steel Still Tubes for Refinery Service	71	0	61
II. PROPOSED REVISIONS OF STANDARDS			
Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 39)	60	0	72
Specifications for Quenched High-Carbon-Steel Splice Bars (A 49 – 21)	60	2	70
Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A 68 – 27)	72	0	60
Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34)	80	0	52
Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 – 33)	86	5	41
Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 33)	77	2	53
III. PROPOSED REVISION OF TENTATIVE STANDARD			
Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 34 T)	74	0	58
IV. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Specifications for Heat-Treated Steel Elliptical Springs (A 147 – 33 T)	68	1	63
V. ADOPTION OF TENTATIVE REVISIONS OF STANDARDS AS STANDARD			
Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 33)	77	0	55
Specifications for Rail-Steel Concrete Reinforcement Bars (A 16 – 33)	73	1	58
VI. WITHDRAWAL OF TENTATIVE STANDARD			
Specifications for Carbon-Steel Castings for Industrial, Railroad and Marine Uses (A 154 – 33 T)	83	1	48
VII. APPROVAL OF ADDITIONS TO LIST OF SPECIFICATIONS			
List of Specifications for Steel Suitable for Fusion Welding (A 151 – 33), immediate inclusion of reference to following:			
Specifications for Mild Steel Plates (A 10 – 34)	88	0	44
Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 33 T)	79	2	51
Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates Over 2 in. up to and Including 4 in. in Thickness) (A 150 – 33 T)	79	2	51

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[1] See Editorial Note, p. 67.—ED.

[2] 1933 Book of A.S.T.M. Standards, Part I, p. 77.

[3] 1934 Supplement to Book of A.S.T.M. Standards, p. 16.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, pp. 533 and 539, respectively (1933); also 1934 Book of A.S.T.M. Tentative Standards, pp. 1 and 7, respectively.

The recommendations appearing in this report have been referred to letter ballot of the committee, which consists of 206 members; 132 members returned their ballots, with the results shown in Table I.

ACTIVITIES OF SUBCOMMITTEES

Certain important features of the committee's work are discussed below, grouped in the order of the respective subcommittees responsible.

Subcommittee I on Steel Rails and Accessories (E. F. Kenney, chairman).—Because of the extensive use of the Standard Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 30) in export trade, revisions of these specifications in the interest of clarifying certain specified requirements, as appended hereto,[1] are recommended for publication as tentative. The description of the drop testing procedure is the same as that formerly included in the specifications as issued in 1924.

The subcommittee recommends that the appended changes[2] involving chemical and physical properties of the Standard Specifications for Quenched High-Carbon-Steel Splice Bars (A 49 – 21) be published as a tentative revision in order to bring the requirements into conformity with those of the specifications of the American Railway Engineering Association for the same product.

This subcommittee is taking part in a joint study with representatives of the Institute of Bolt, Nut and Rivet Manufacturers and the A.R.E.A. to consider proposed changes in the Standard Specifications for Quenched Carbon-Steel and Alloy-Steel Track Bolts (A 50 – 33).[3]

Subcommittee II on Structural Steel for Bridges, Buildings and Rolling Stock (A. W. Carpenter, chairman).—A recommended practice for the conditioning of rolled steel surfaces by welding has been formulated and will be submitted shortly for approval and subsequent publication.[4]

This subcommittee is studying revisions in the Standard Specifications for Structural Nickel Steel (A 8 – 29) and for Structural Silicon Steel (A 94 – 33) and is developing specification requirements for high-strength rivet steel.

Subcommittee IV on Spring Steel and Steel Springs (H. W. Faus, chairman).—Since no criticism has been received of the Tentative Specifications for Heat-Treated Steel Elliptical Springs (A 147 – 33 T), the subcommittee is recommending their adoption as standard.

In order that the Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A 68 – 27) may be in line with the requirements adopted this year by the Association of American

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[1] See p. 1371.—ED.

[2] See p. 1374.—ED.

[3] See Editorial Note, p. 67.—ED.

[4] Subsequent to the annual meeting Committee A-1 presented this to the Society through Committee E-10 on Standards in the form of a proposed revision of the finish clause of the Standard Specifications for Steel for Bridges (A 7 – 34), for Steel for Buildings (A 9 – 34), and for Structural Silicon Steel (A 94 – 33), which was accepted for publication as tentative, see Editorial Note, p. 67.—ED.

Railroads, revisions as appended hereto[1] are recommended for publication as tentative.

Subcommittee V on Steel Reinforcement Bars (H. H. Morgan, chairman).—No major criticism having been received of the tentative revision proposed last year, covering permissible weight variations of individual bars, in the Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 33) and for Rail-Steel Concrete Reinforcement Bars (A 16 – 33), Subcommittee V recommends their adoption as standard.

A request from the Axle Steel Manufacturers Association for separate specifications covering axle-steel concrete reinforcement bars has resulted in proposed tentative specifications, which are appended hereto.[2]

Subcommittee V is developing specification requirements covering fabricated concrete reinforcement material, including welded fabric, bar mats and expanded metal.

Subcommittee IX on Steel Tubing and Pipe (T. G. Stitt, chairman).—A section of this subcommittee has been working for the past two years on the development of requirements covering seamless low-carbon-steel still tubes for refinery service. Representatives of the manufacturers' and refinery interests cooperated and as a result the proposed specifications, appended hereto,[3] are recommended for publication as tentative.

This special committee concurrently has been considering requirements for heat exchanger and condenser tubes and proposed specifications will be submitted shortly.[4] This subcommittee is also developing specifications covering electric-resistance-welded steel and iron boiler tubes and forged steel pipe flanges for general service.[4] A number of desirable revisions in specifications under the jurisdiction of the subcommittee will be submitted shortly for approval.[4]

Subcommittee XII on Methods of Chemical Analysis (G. E. F. Lundell, chairman).—This subcommittee has been working on extensive changes in the Standard Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 24) and of Chemical Analysis of Alloy Steels (A 55 – 24). The subcommittee has expressed its approval of the proposal to combine all A.S.T.M. subcommittees on methods of analyzing ferrous metals into a new standing committee, which is in course of organization. Committee A-1 will be represented on the new committee by Messrs. C. B. Francis and M. E. McDonnell.

Subcommittee XIII on Methods of Physical Test (L. H. Fry, chairman).—During the past year a complete reorganization of Subcommittee XIII has been effected with the addition of a number of new members especially concerned with test methods. Closer contact with activities of Committee

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[1] See p. 1378.—ED.
[2] See p. 552.—ED.
[3] See p. 590.—ED.
[4] See Editorial Note, p. 67.—ED.

E-1 on Methods of Testing is being arranged and representatives of Committee A-1 have been appointed to serve on various subdivisions of Committee E-1 in order to cooperate in their respective programs of work.

Committee A-1 wishes to assist in clarifying test methods as to their applicability for research or investigational testing as distinct from routine or commercial methods and to indicate specifically materials to which the test methods apply. Subcommittee XIII is prepared to undertake this work and plans are being developed to draw up methods of tension testing applicable to steels covered by specifications under the jurisdiction of Committee A-1. These will be referred to Committee E-1 for consideration in connection with the Standard Methods of Tension Testing of Metallic Materials (E 8 – 33).

Subcommittee XV on Commercial Bar Steels (J. J. Shuman, chairman).—In line with developments in production of commercial bar steels and to meet more fully the needs of consuming interests, including the agricultural implement and automotive industries, extensive revisions, as appended hereto,[1] in the Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 – 33) and for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 33) are recommended for publication as tentative. The major revision consists in expanding the series of steels covered to include the S.A.E. open-hearth grades and free-cutting grades in full.

Subcommittee XIX on Sheet Steel and Steel Sheets (A. L. Davis, chairman).—This subcommittee has developed a number of desirable revisions in the Tentative Specifications for Cold-Rolled Strip Steel (A 109 – 34 T) to meet certain objections and to increase their practical value. These revisions will be submitted to Committee A-1 in June with the recommendation that they be submitted to the Society for acceptance.[2]

Subcommittee XXI on Steel for Welding (N. L. Mochel, chairman).—The study of the effect of carbon and manganese with respect to weldability, which this subcommittee has had under way during the past year, is to be continued and an effort made to institute an intensive program of actual test work.

The subcommittee has taken the initiative in instituting conferences, jointly sponsored by the American Welding Society, and the A.S.T.M. with various national organizations interested in specifications for filler metal for use in fusion welding, in an attempt to harmonize existing specification requirements which differ in minor respects.

Subcommittee XXII on Valves, Fittings, Piping and Flanges for High-Temperature Service (A. E. White, chairman).—Since the publication of the Tentative Specifications for Seamless Alloy-Steel Pipe for Service at

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[1] See p. 1381.—ED.

[2] See Editorial Note, p. 67.—ED.

Temperatures from 750 to 1100 F. (A 158 – 34 T), a number of desirable changes have been brought to the attention of the subcommittee. These are covered in the proposed revision which is given in the Appendix.

Specifications covering nuts and bolting for service at temperatures from 750 to 1100 F. are nearing completion and will be submitted in the near future. There are appended hereto[1] for information proposed Specifications for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at temperatures from 750 to 1100 F. These will be recommended by the subcommittee for publication as tentative.[2]

Subcommittee XXII is now considering a simplified system of marking the products covered by the several specifications for piping materials up to 1100 F. This will provide that similar alloys in the respective specifications will have similar designations identified according to the product, that is casting, or pipe, etc. It is anticipated that Subcommittee XXII will recommend these revised materials designations at the June meeting for subsequent inclusion in the respective specifications when republished.

The subcommittee's section on high temperature data has held several meetings and carried on considerable correspondence. This section has attempted to obtain creep data from all of the sources of which it had knowledge. These data are considered essential in connection with specifications the subcommittee is developing for piping material for use at temperatures from 750 to 1100 F. The extensive data, which have been tabulated and plotted, will be submitted to the members of Subcommittee XXII for consideration and action. The section on data is of the opinion that it is impossible, as yet, to give safely definite theoretical creep values for all the materials referred to in specifications under the jurisdiction of Subcommittee XXII.

This report has been submitted to letter ballot of the committee, which consists of 206 members; 118 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. H. MORGAN,
Chairman.

H. P. BIGLER,
Secretary.

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[1] See p. 616.—ED.

[2] See Editorial Note, below.—ED.

EDITORIAL NOTE

Subsequent to the annual meeting, Committee A-1 on Steel presented to the Society on August 22, 1935, through Committee E-10 on Standards the following additional recommendations:

Proposed Tentative Specifications for:

Carbon-Steel Plates for Boilers and Other Pressure Vessels for Stationary Service, see p. **527**, as a revision of and to supersede the existing Standard

Specifications for Boiler and Firebox Steel for Stationary Service (A 70 – 33).

Carbon-Steel and Alloy-Steel Castings for Railroads, see p. **561**, as a revision of and to supersede the existing Standard Specifications for Carbon-Steel Castings for Railroads (A 87 – 27).

Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes, see p. **579**.

Seamless Cold-Drawn Steel Heat-Exchanger and Condenser Tubes (Sizes ½ in. to but not Including 2 in. in Outside Diameter), see p. **585**.

Carbon-Steel Castings for Miscellaneous Industrial Uses, see p. **568**, as a tentative revision of the existing Standard Specifications for Carbon-Steel Castings (A 27 – 24).

Forged or Rolled Steel Pipe Flanges for General Service, see p. **575**.

Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for Service at Temperatures from 750 to 1100 F., see p. **616**.

Heat-Treated Carbon- and Alloy-Steel Track Bolts, see p. **556**, as a tentative revision of the existing Standard Specifications for Quenched Carbon-Steel Track Bolts (A 50 – 33) and for Quenched Alloy-Steel Track Bolts (A 51 – 33).

Revision of Tentative Specifications for:

High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness) (A 149 – 33 T), see p. **534**.

High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates over 2 in. up to and Including 4 in. in Thickness) (A 150 – 33 T), see p. **539**.

Cold-Rolled Strip Steel (A 109 – 34 T), see p. **544**.

Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 – 34 T), see p. **597**.

Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 – 35 T), see p. **605**.

Tentative Revision of Standard Specifications for:

Steel for Bridges (A 7 – 34), see p. **1379**.

Steel for Buildings (A 9 – 34), see p. **1380**.

Structural Silicon Steel (A 94 – 33), see p. **1380**.

Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34), see p. **1384**.

Withdrawal of Standard Specifications for:

Boiler and Firebox Steel for Stationary Service (A 70 – 33).

Carbon-Steel Castings for Railroads (A 87 – 27).

The above recommendations were accepted by Committee E-10 and appear respectively in this volume on the pages given above.

APPENDIX

PROPOSED REVISIONS IN TENTATIVE STANDARD FOR STEEL

Proposed Revision of Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A.S.T.M. Designation: A 158 - 34 T):[1]

Section 5.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

5. (*a*) All ferritic steels [other than those] covered in Section 3 [(*c*)] shall be furnished in a full-annealed or normalized and drawn condition as stated in the purchase order. If [tested] *furnished* in the normalized and drawn condition, the temperature for drawing shall be at least 200 F. above the service temperature as given in the purchase order (*Note 1*).

(*b*) *At the option of the purchaser*, all austenitic steels shall be stabilized (*Note 2*) according to present accepted practice.

Note.—Add the following notes at the end of Section 5:

NOTE 1.—Certain of the ferritic steels covered by these specifications will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 to 6 per cent chromium steels, F_5. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging and hot bending, should be followed by heat treating.

NOTE 2.—Fabricating operations involving upsetting, flanging, bending, and forming often make restabilizing desirable to insure adequate corrosion resistance, depending upon service conditions.

Section 6.—In the table in this section, change "Grade A_4" to read "Grade F_9."

Section 8.—Change Paragraph (*b*) to read as follows by the addition of the italicized words:

(*b*) Drillings for analysis *from pipe* shall be taken from several points around each pipe selected for analysis. *Drillings for analysis from billets shall be taken at a point midway between the outside and center of the billet by drilling parallel to the axis.*

Delete from Paragraph (*c*) the last sentence, which reads as follows:

When drillings for analysis are taken from the billet, the sample shall be taken at a point midway between the outside and center of the piece by drilling parallel to the axis.

Section 15 (a).—Change to read as follows by the omission of the words and figures in brackets:

15. (*a*) If the results of any [chemical or] physical tests of any lot do not conform to the requirements specified in Sections [8 (*a*)] 9, 11, or 12, retests shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 617 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 75.

REPORT OF COMMITTEE A-2
ON
WROUGHT IRON

Committee A-2 on Wrought Iron held one meeting during the year, in Philadelphia, Pa., on March 5, 1935. A second meeting will be held prior to the presentation of this report to the Society when the report will be reviewed and other matters considered.

The committee records with sincere regret the loss through death of one of its most esteemed members, Mr. J. B. Schlossberg.

Recommendations Affecting Standards

I. Proposed Tentative Standards.—The committee recommends for publication as tentative the following two specifications, as appended hereto:[1]

Tentative Specifications for Uncoated Wrought-Iron Sheets
Tentative Specifications for Zinc-Coated (Galvanized) Wrought-Iron Sheets

The Specifications for Galvanized Wrought-Iron Sheets have been referred to Committee A-5 on Corrosion of Iron and Steel for review of the requirements respecting the zinc coating of the sheets.

II. Proposed Revisions of Tentative Standards.—The committee recommends that the following specifications be revised in accordance with the changes given in the Appendix, and the specifications as revised continued as tentative:

Tentative Specifications for Wrought-Iron Plates (A 42 – 34 T)
Tentative Specifications for Wrought-Iron Rivets and Rivet Rounds (A 152 – 33 T)

III. Proposed Revisions of Standards.—The committee recommends that revisions, as appended hereto,[2] of the six standard specifications listed below be published as tentative for one year before referring them to letter ballot of the Society for adoption as standard:

Standard Specifications for:

Common Iron Bars (A 85 – 27)
Refined Wrought-Iron Bars (A 41 – 30)
Staybolt, Engine-Bolt and Other High-Grade Wrought-Iron Bars (A 84 – 33)
Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 30)
Hollow Rolled Staybolt Iron (A 86 – 30)
Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34)

With respect to the proposed revision in the Standard Specifications A 83 – 34, which is under the joint jurisdiction of Committee A-1 on Steel and Committee A-2, Subcommittee I on Tubes and Pipe (G. H. Woodroffe, chairman) of Committee A-2 concurs in the recommendation of Subcommittee IX on Steel Tubing and Pipe of Committee A-1 that the following proposed modification in the marking clause, Section 17 (*b*), of these specifications be published as tentative:

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[1] See pp. 701 and 704.—Ed.
[2] See p. 1388.—Ed.

Section 17 (*b*).—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

> (*b*) On tubes less than $1\frac{1}{4}$ in. in diameter and on all tubes under 3 ft. in length, the name, [or] initials, or brand of the manufacturer, *the grade and hydrostatic pressure in pounds at which it was tested* shall be legibly stenciled or indicated on a sticker applied on each tube.

IV. Adoption of Tentative Revision of Standard as Standard. The committee recommends that the tentative revision in the Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 30), prepared by Subcommittee III on Staybolt and Engine-Bolt Iron (E. J. Edwards, chairman), and submitted last year for publication as tentative be approved for reference to letter ballot of the Society for adoption as standard. The revision is as follows:

Section 11.—Change the center heading, "Permissible Variations in Gage," which precedes this section, to read, "Permissible Variations."

Add the following sentence as Paragraph (*b*), lettering the present section as Paragraph (*a*):

> (*b*) The diameter of hole shall be $\frac{3}{16}$ in. within a permissible variation of – 0 and + $\frac{1}{32}$ in. A rod $\frac{1}{8}$ in. in diameter shall pass freely through the entire length of the tell-tale hole. The tell-tale hole may be off center $\frac{1}{16}$ in., maximum.

The recommendations appearing in this report have been referred to letter ballot of the committee, which consists of 55 members; 48 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Specifications for Uncoated Wrought-Iron Sheets	36	0	12
Specifications for Zinc-Coated (Galvanized) Wrought-Iron Sheets	35	0	13
II. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Specifications for Wrought-Iron Plates (A 42 – 34 T)	40	0	8
Specifications for Wrought-Iron Rivets and Rivet Rounds (A 152 – 33 T)	42	0	6
III. PROPOSED REVISION OF STANDARDS			
Specifications for Common Iron Bars (A 85 – 27)	44	0	4
Specifications for Refined Wrought-Iron Bars (A 41 – 30)	44	0	4
Specifications for Staybolt, Engine-Bolt and Other High-Grade Wrought-Iron Bars (A 84 – 33)	44	0	4
Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 30)	41	0	7
Specifications for Hollow Rolled Staybolt Iron (A 86 – 30)	40	0	8
Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 34)	36	0	12
IV. ADOPTION OF TENTATIVE REVISION OF STANDARD AS STANDARD			
Specifications for Hollow Rolled Staybolt Iron (A 86 – 30)	40	0	8

This report has been submitted to letter ballot of the committee which consists of 55 members; 42 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. W. FAUS,
Chairman.

G. H. WOODROFFE,
Secretary.

APPENDIX

PROPOSED REVISIONS IN TENTATIVE STANDARDS FOR WROUGHT IRON

In this Appendix are given proposed revisions in specifications covering wrought iron as referred to earlier in this report. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

Proposed Revisions of Tentative Standards

Proposed Revision of Tentative Specifications for Wrought-Iron Plates (A.S.T.M. Designation: A 42 - 34 T):[1]

Section 8 (*b*).—Change the first sentence from its present form: namely,

> If any test specimen fails to conform to the requirements specified by reason of an apparent local defect, a retest shall be allowed.

to read as follows:

> If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen fails to meet the physical requirements of Section 4 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different plate will be allowed.

Proposed Revision of Tentative Specifications for Wrought-Iron Rivets and Rivet Rounds (A.S.T.M. Designation: A 152 - 33 T):[2]

Section 7 (*b*).—Change to read as follows by the addition of the italicized words and figure and the omission of those in brackets:

> (*b*) If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen *fails to meet the physical requirements of Section 4 and* breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual [bar] *specimen* shall be rejected and one retest from a different bar [shall] *will* be allowed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 648 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 121.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 587 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 127.

REPORT OF COMMITTEE A-3

ON

CAST IRON

Since the 1934 annual meeting of the Society, Committee A-3 on Cast Iron held one meeting at Philadelphia, Pa., on March 5, 1935. A second meeting will be held prior to the presentation of this report to the Society, at which time the report will be reviewed and other matters considered. The present membership of the committee is 93 of whom 31 are classified as producers, 38 as consumers, and 24 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

I. *Proposed Tentative Standard:*

The committee recommends that the proposed Tentative Specifications for Automotive Gray-Iron Castings be accepted for publication as tentative as appended hereto.[1]

II. *Proposed Revisions of Tentative Standards:*

The committee recommends that the following tentative specifications be revised as indicated and continued as tentative:

Tentative Specifications for Gray-Iron Castings (A 48 – 32 T), revised as appended hereto.[2]

Tentative Specifications for Cast-Iron Culvert Pipe (A 142 – 34 T), revised as proposed by Subcommittee VIII.

The above recommendations have been submitted to letter ballot of the committee, which consists of 94 members; 54 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Specifications for Automotive Gray-Iron Castings	34	0	20
II. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Specifications for Gray-Iron Castings (A 48 – 32 T)	46	1	7
Specifications for Cast-Iron Culvert Pipe (A 142 – 34 T)	37	0	18

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Pig Iron (C. D. Mathews, chairman).—A revision of the existing Standard Specifications for Foundry Pig Iron (A 43 – 24) is desired and the subcommittee has been asked to make a report at the June meeting.

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[1] See p. 709.—ED.

[2] See p. 713.—ED.

Subcommittee IV on Car Wheels (F. K. Vial, chairman).—This subcommittee has been engaged in the revision of the Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 30 T). It is expected that the revised specifications will be presented to Committee A-3 at its fall meeting.

Subcommittee V on Light Gray-Iron Castings (E. B. Sherwin, chairman).—There appears to be a demand for specifications for light gray-iron castings and the subcommittee has been instructed to make a report at the June meeting.

Subcommittee VI on General Castings (J. W. Bolton, chairman).—Since the Tentative Specifications for Gray-Iron Castings (A 48 – 32 T) were issued in 1932, considerable investigative work has been done, particularly in correlation between transverse and tension tests and also in reference to the value of the separately cast tension test bar. As a result, the separately cast tension bar is eliminated in the revised specification and a new set of values is substituted for the values for the transverse tests. Subcommittee VI has prepared an extensive revision of the Tentative Specifications A 48 based on information and data furnished by Subcommittee XI on Methods of Testing. The revised specifications are appended hereto.[1]

Subcommittee VIII on Cast-Iron Culvert Pipe (E. F. Kelley, chairman).—Subcommittee VIII has prepared the following revision of the Tentative Specifications for Cast-Iron Culvert Pipe (A 142 – 34 T):[2]

Section 7 (b).—Add the following as a new paragraph (*b*), relettering the present paragraph as Paragraph (*c*):

> (*b*) The metal in the barrel of the finished pipe shall contain not more than 0.90 per cent of combined carbon. The test sample for the determination of combined carbon shall be composed of drillings representative of the full thickness of the pipe barrel.

Subcommittee X on Nomenclature and Definitions (Robert Job, chairman).—Definitions of terms relating to cast iron have been offered to Committee E-8 on Nomenclature and Definitions. These definitions have been approved by Committee A-3 and are appended hereto[3] for information. The subcommittee was asked to develop definitions for "modulus of rupture" and "modulus of elasticity," particularly in respect to cast iron.

Subcommittee XI on Methods of Testing (R. S. MacPherran, chairman).—This subcommittee was quite active during the past year in securing information which would permit of a revision in the Tentative Specifications for Gray-Iron Castings (A 48 – 32 T). The report of the subcommittee is appended hereto.

Subcommittee XVIII on Automotive Castings (A. L. Boegehold, chairman).—There has been considerable demand for separate specifications for automotive gray-iron castings. Subcommittee XVIII has worked in cooperation with the Gray Iron Committee of the Iron and Steel Division of the Society of Automotive Engineers in the development of the Proposed Tentative Specifications for Automotive Gray-Iron Castings appended hereto,[1] which are recommended for publication as tentative. Identical specifications have also been adopted as standard by the Society of Automotive Engineers.

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[1] See p. 713.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 654 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 140.

[3] See p. 80.—ED.

This report has been submitted to letter ballot of the committee which consists of 94 members; 47 members returned their ballots, of whom 41 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

HYMAN BORNSTEIN,
Chairman.

E. K. SMITH,
Secretary.

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[1] See p. 709.—ED.

REPORT OF SUBCOMMITTEE XI ON METHODS OF TESTING

The principal business before Subcommittee XI during the past year has been to supply information which would enable Subcommittee VI on General Castings to revise the Tentative Specifications for Gray-Iron Castings (A 48 – 32 T).[1]

It was recognized that the transverse loads shown in these specifications needed revision. A large number of tests were made by members of the subcommittee and others. These loads were averaged and average figures were supplied to Subcommittee VI and used in the revision of the specifications. Sufficient data on deflection values have not been received to justify the inclusion of deflection values in the specifications.

The value of the separately cast tension test specimen in Tentative Specifications A 48 – 32 T has been questioned for several years. A number of tests made by several investigators indicated that the separately cast bar could be eliminated and satisfactory test results secured from tension test specimens machined from transverse test bars. Some of this work was reported last year and included in the annual report of Committee A-3.[2] A comprehensive investigation by J. T. MacKenzie of the American Cast Iron Pipe Co. confirmed results obtained by other investigators. The data reported by Mr. MacKenzie are presented in Tables I and II. Acknowledgment is made to the Pittsburgh Testing Laboratory for aid in making tension tests. On the basis of results obtained, it was recommended to Subcommittee VI that the separately cast tension test specimen be eliminated from the specifications.

The problem of sections of castings to be represented by the various test bars was considered. The figures given in Tentative Specifications A 48 – 32 T were not in agreement with the results obtained by several investigators. Recommendations were made to revise the figures in the specifications and the new figures are shown in the revised specifications appended hereto.[3] It appears that there is a need for a bar larger than the 2-in. diameter bar and a suggestion has been made for a 3-in. diameter bar tested on 24-in. supports.

It was pointed out that it was not commercially practicable at present consistently to produce bar C for class No. 60 iron shown in the specifications. Consequently, this bar has been eliminated from class No. 60 in the revised specifications.[3]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 625 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 132.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 148 (1934).

[3] See p. 713.—ED.

TABLE I.—RESULTS OF TENSILE STRENGTH TESTS OF GRAY-IRON CASTINGS USING MACHINED AND SEPARATELY CAST SPECIMENS.

NOTE.—The bars were all cast in the same manner, in dry, blacked molds. The transverse bars were poured by the Saeger method and the separately cast tension specimens were poured in accordance with the Tentative Specifications for Gray-Iron Castings (A 48 - 32 T).

Set	Tensile Strength, lb. per sq. in.									
	Tension Specimens Machined from Transverse Bars					Separately Cast Tension Specimens				
	BAR A, 0.505 IN. IN DIAMETER									
					Average					Average
No. 22	37 400	37 100	37 300	......	37 300	34 600	28 400[a]	30 300[a]	......	34 600
No. 23	35 000	26 700[a]	......	b	......	......	......	......	......	......
	31 800	31 600	29 200	......	......	......	......	......	......	......
	34 000	31 000	30 800	29 000	31 500	33 100	32 300	31 700	......	32 400
No. 62	34 000	31 900	......	......	33 000	33 400[a]	34 800	35 500	......	35 100
No. 65	34 600	34 500	33 800	......	34 300	34 000[a]	34 500	36 200	......	35 400
No. 66	22 700[a]	c	c	......	......	31 600[a]	33 600	c	......	33 600
No. 68	c	c	c	......	......	43 100	33 800[a]	32 000[a]	c	43 100
No. 69	64 800	62 500	64 000	......	63 700	57 000	52 100[a]	56 000[a]	b	57 000
No. 70	43 500	42 100	39 500	......	41 700	33 000[a]	38 800[a]	41 200	40 200	40 600
No. 71	33 500	37 100	32 700	......	34 400	23 000[a]	30 400[a]	32 500	b	32 500
No. 72	36 300	36 100	36 800	......	36 400	38 200	31 800[a]	37 200	34 300[a]	37 700
No. 73	52 300	52 000	53 100	......	52 500	45 700	43 100	42 000[a]	47 800	45 500
No. 74	43 300	41 800	42 000	......	42 400	25 300[a]	36 500[a]	34 800[a]	42 500	42 500
No. 76	49 100	48 300	47 800	......	48 400	36 300	32 900[a]	39 500	44 200	40 000
No. 77	41 700	41 200	42 100	......	41 700	43 800	40 700	38 300	38 000	40 500
No. 79	68 000	62 200	64 500	......	64 900	63 300	59 200	61 100	60 500	61 000
No. 85	20 300	21 400	20 400	22 200	21 100	22 000	15 000[a]	15 000[a]	13 000[a]	22 000
	BAR B, 0.800 IN. IN DIAMETER									
					Average					Average
No. 22	32 400	32 500	32 500	......	32 500	32 800	32 300	31 000	......	32 000
No. 23	28 700	27 900	24 000[a]	28 300	......	......	......	......	......	......
	28 300	27 500	26 000	30 900	28 200	31 000	30 800	31 600	......	31 100
No. 62	33 500	32 000	32 800	......	32 800	30 100	32 500	b	......	31 300
No. 65	32 300	30 700	......	......	31 500	33 200	33 200	33 300	......	33 200
No. 66	45 500[a]	47 600	......	......	47 600	b	b	b	......	......
No. 68	38 900	39 900	......	......	39 400	42 000	41 000[a]	34 000[a]	b	42 000
No. 69	63 100	63 500	63 500	......	63 400	54 100	53 000[a]	53 300	b	53 700
No. 70	40 000	39 800	36 500[a]	......	39 900	35 800[a]	35 800[a]	37 500	37 700	37 600
No. 71	31 600	32 300	......	......	32 000	30 100[a]	29 700[a]	31 000	b	31 000
No. 72	34 700	33 800	33 900	......	34 100	36 200	36 600	35 800	33 500[a]	36 200
No. 73	45 500	45 300	44 000	......	44 900	41 600	40 700	35 900[a]	39 400[a]	41 200
No. 74	40 700	40 100	39 200	......	40 000	30 300[a]	26 700[a]	28 400[a]	b	......
No. 76	41 200	43 700	40 900	......	41 900	37 400	37 300	38 200	28 600[a]	37 600
No. 77	37 600	35 400	37 000	......	36 700	33 100	38 000	38 000	41 300	37 800
No. 79	56 000	60 100	58 100	......	58 100	58 500	55 800	58 900	58 000	57 800
No. 85	20 700	20 000	21 000	......	20 600	20 200	18 700[a]	18 600[a]	b	20 200
	BAR C, 1.25 IN. IN DIAMETER									
					Average					Average
No. 22	25 300	24 800	24 100	......	......	......	......	......	......	......
	24 800	24 400	25 100	......	24 800	24 600	26 600	25 900	......	25 700
No. 23	23 200	21 500[a]	......	......	23 200	23 300	19 300[a]	23 200	......	23 200
No. 62	20 400	20 500	21 200	......	20 700	b	b	b	......	......
No. 65	22 800	22 200	23 900	......	23 000	27 100	24 900	26 000	......	26 000
No. 66	38 400	37 500	37 800	......	37 900	36 500	b	......	......	36 500
No. 68	38 100	37 900	......	......	38 000	25 900[a]	26 800[a]	27 800[a]	28 400[a]	......
No. 69	46 700	47 800	47 300	......	47 300	47 000	46 800	46 200	......	46 700
No. 70	28 100	29 600	29 900	......	29 200	30 800	30 900	24 000[a]	24 000[a]	30 800
No. 71	27 500	28 700	26 400	......	27 500	21 900[a]	28 700	26 300[a]	b	28 700
No. 72	26 200	26 900	25 900	......	26 300	28 300	29 100	28 400	27 000	28 200
No. 73	34 800	36 100	36 200	......	35 700	34 800	34 200	34 600	33 900	34 400
No. 74	36 800	35 300[a]	36 300	......	36 500	b	b	b	......	......
No. 76	41 500	41 700	41 600	......	41 600	33 600	32 300	34 200	32 900	33 300
No. 77	29 500	30 000	28 700	......	29 400	33 700	32 900	32 600	32 500	32 900
No. 79	51 300	53 000	55 000	......	53 100	52 800	53 200	50 400	52 700	52 300
No. 85	17 900	15 900	16 600	......	16 800	15 200	15 900	17 400	19 800	17 100

[a] Flawed specimens, not included in average.
[b] Unavailable.
[c] Discarded in machine shop, flawed.

The subcommittee was asked to give a definite recommendation on a method of making transverse test bars. It was found that a number of methods were giving satisfactory results and it was therefore recommended that the manufacturer be permitted to make the bars as he saw fit. The problem is to produce bars free from flaws.

TABLE II.—SUMMARY SHOWING PERCENTAGE RATIO OF TENSILE STRENGTH AND PERCENTAGE OF ACCEPTABLE TEST SPECIMENS.

Set	Percentage Ratio of Tensile Strength: Separately Cast Tension Specimen / Tension Specimen Machined from Transverse Bar			Percentage of Good Bars Received from Machine Shop					
				Tension Specimen Machined from Transverse Bar			Separately Cast Tension Specimen		
	Bar A Specimens	Bar B Specimens	Bar C Specimens	Bar A Specimens	Bar B Specimens	Bar C Specimens	Bar A Specimens	Bar B Specimens	Bar C Specimens
No. 22	93	99	105	100	100	100	33	100	100
No. 23	103	110	100	80	87	50	100	100	67
No. 62	106	96	....	100	100	100	67	33	0
No. 65	103	105	113	100	100	100	67	100	100
No. 66	....	....	96	0	50	100	33	0	50
No. 68	....	107	....	0	100	100	25	25	0
No. 69	90	85	99	100	100	100	25	50	100
No. 70	97	94	105	100	67	100	50	50	50
No. 71	95	97	104	100	100	100	25	25	25
No. 72	104	106	107	100	100	100	50	75	100
No. 73	87	92	96	100	100	100	75	50	100
No. 74	100	....	....	100	100	67	25	0	0
No. 76	83	90	80	100	100	100	75	75	100
No. 77	97	103	112	100	100	100	100	100	100
No. 79	94	99	98	100	100	100	100	100	100
No. 85	104	98	102	100	100	100	25	25	100
Average	97	99	101	85	94	96	54	58	71
Grand Average		99			93			58	

Respectfully submitted on behalf of the subcommittee,

R. S. MACPHERRAN,
Chairman.

APPENDIX

PROPOSED DEFINITIONS OF TERMS RELATING TO CAST IRON[1]

These are **proposed definitions** and are published as information only. Suggestions for revision are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Cast Iron.—Iron containing so much carbon that as cast it is not usefully malleable at any temperature.

Usually from 1.7 to 4.5 per cent carbon is present and in most cases an important percentage of silicon.

Pig Iron.—Cast iron usually produced by smelting iron ores in the blast furnace. It may have been cast into pigs or held in a molten condition for charging into a steel-making furnace.

Gray Iron.—Cast iron having a gray fracture. It is readily machinable with ordinary tools. The combined carbon usually does not exceed 0.8 per cent.

White Iron.—Cast iron having a white fracture. It is very hard and difficult to machine. The carbon is practically all in the form of iron carbide.

Mottled Iron.—Cast iron having a mottled fracture. The structure and fracture show a mixture of gray iron and white iron.

Malleable Cast Iron.—Iron, white as cast, which has been made malleable by annealing.

Semisteel.—A vague trade name for various cast-iron products made by adding steel to the melting charge.

NOTE.—The term never had a real meaning and should be considered obsolete.

High-Test Cast Iron.—A term formerly used to designate gray cast iron having a minimum tensile strength of 28,000 lb. per sq. in.

NOTE.—This term should be considered obsolete since the Tentative Specifications for Gray-Iron Castings (A.S.T.M. Designation: A 48 – 35 T) of the American Society for Testing Materials[2] definitely classify gray-iron castings.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

[2] See p. 713.

REPORT OF COMMITTEE A-5
ON
CORROSION OF IRON AND STEEL

Committee A-5 on Corrosion of Iron and Steel has held two meetings during the past year; one at the Annual Meeting of the Society in Atlantic City, N. J., and the other in March, 1935, at the Spring Group Meetings of A.S.T.M. Committees held in Philadelphia, Pa. The activities of the committee have been concentrated along two lines: (*1*) Outdoor exposure corrosion projects already under way or actively projected, pointed toward evaluation of the outdoor serviceability of bare and coated ferrous materials and (*2*) Preparation of new standards or revision of existing standards for coated ferrous materials.

Since the 1934 Annual Meeting, 3 new members have been elected and 3 resignations accepted, the committee membership now totaling 127, of whom 58 are classified as producers and 69 as non-producers; of the latter, 48 are consumer and 21 general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

I. Proposed Tentative Standards:

The committee recommends the following three specifications relating to plated coatings on steel for publication as tentative as appended hereto:[1]

Proposed Tentative Specifications for Electrodeposited Coatings of Zinc on Steel
Proposed Tentative Specifications for Electrodeposited Coatings of Cadmium on Steel
Proposed Tentative Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel

These specifications were developed in cooperation with the American Electroplaters' Society and the National Bureau of Standards through the Joint Research Committee on Investigation of Electroplated Coatings. They are the first proposed standards prepared by the Society relating to plated coatings on steel and it is expected that as a result of comments made following their publication as tentative subsequent revisions may be desirable. These specifications will serve a very useful purpose in setting up minimum requirements for plated coatings designed for types of service as classified in the specifications. Critical comments on these tentative specifications are desired by the committee.

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[1] See pp. 682, 684 and 686.—ED.

II. Proposed Revisions of Standards:

The committee recommends that the following two standards be revised editorially so that references to determining the requirements for weight and uniformity of coating shall be in accordance with the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A 90 – 33). These specifications at present refer to the Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 30), the withdrawal of which is being recommended, and it is accordingly desirable to reword certain sections in order to clarify requirements in accordance with the Standard Methods A 90:

Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 30)
Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 30)

III. Adoption of Tentative Standard as Standard:

The committee recommends that the Tentative Recommended Practice for Safeguarding Against Embrittlement of Hot-Galvanized Structural Steel Products and Procedure for Detecting Embrittlement (A 143 – 32 T)[1] be submitted to letter ballot of the Society for adoption as standard. This Recommended Practice has been published as tentative since 1932 and no comments have been received which would indicate the desirability of any revision in its present form.

IV. Withdrawal of Standard and Tentative Standards:

The committee recommends the withdrawal of the following standard and tentative standards:

Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 30)[2]
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 32 T)[3]
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 32 T)[3]

The Standard Methods A 110 were written primarily to cover methods for testing hot-dipped zinc coatings on wire and wire products but recently prepared methods for determining weight and uniformity of zinc coatings have been incorporated in the Standard Methods A 90 – 33 which make obsolete the procedure described in Methods A 110.

It is believed that the revised specifications for farm fencing and barbed wire, when finally completed, will be quite different in form from the Tentative Specifications A 116 – 32 T and A 121 – 32 T, and, since considerable work is still required before such revisions can be made, it has appeared desirable to withdraw the present tentative specifications. The existing standard specifications for these materials, with editorial changes as mentioned above, are being retained until completion of the revised specifications.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 615 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 117.
[2] 1933 Book of A.S.T.M. Standards, Part I, p. 324.
[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 599, 606 (1932); also 1934 Book of A.S.T.M. Tentative Standards, pp. 109, 106.

The recommendations in this report have been submitted to letter ballot of the committee, which consists of 127 members; 80 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Specifications for Electrodeposited Coatings of Zinc on Steel	64	1	13
Specifications for Electrodeposited Coatings of Cadmium on Steel	59	0	19
Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel	53	1	24
II. PROPOSED REVISIONS OF STANDARDS			
Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 30), editorial change	61	0	18
Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 30), editorial change	61	0	18
III. ADOPTION OF TENTATIVE RECOMMENDED PRACTICE			
Recommended Practice for Safeguarding Against Embrittlement of Hot-Galvanized Structural Steel Products and Procedure for Detecting Embrittlement (A 143 – 32 T)	60	0	18
IV. WITHDRAWAL OF STANDARD AND TENTATIVE STANDARDS			
Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 30)	66	0	13
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 32 T)	63	0	16
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 32 T)	63	0	16

ACTIVITIES OF SUBCOMMITTEES

Subcommittee III on Inspection of Annapolis Tests (E. S. Taylerson, chairman).—Since the inspection on April 26, 1934, of the Nos. 16 and 22 gage sheets exposed at Annapolis, Md., and recorded in the 1934 report, one further inspection on November 2, 1934, was made of these corrugated sheets.[1] At this inspection, after an exposure of 216 months (18 yr.), three failures were observed in the No. 22 gage non-copper-bearing sheets. The three failures noted were in sheet A 5 (bessemer steel), sheet X 14 (low-copper pure iron) and sheet Y 3 (low-copper wrought iron). At the November inspection no additional failures were noted in the No. 22 gage copper-bearing sheets and none of the No. 16 gage sheets have as yet failed. The tests are being continued.

Subcommittee V on Total Immersion Tests (F. B. Olcott, chairman).—The routine monthly inspections of the No. 16 gage copper-bearing and non-copper-bearing sheet steel specimens immersed in sea water at the U. S. Navy Yard, Portsmouth, N. H., and at the U. S. Naval Station, Key West, Fla., have been made by Subcommittee V during the past year. The failures noted at these various inspections are recorded in Tables I and II (Plates I and II) which also include a tabulation of the failures observed at previous inspections.

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[1] For detailed tabulations of failures observed in the tests at Annapolis, see Table I (Plate I) of the 1934 Report of Committee A-5, *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 156 (1934).

The riveted plates described in the 1932 report[1] have been given the annual inspection. The inspection of the plates at the U. S. Navy Yard, Portsmouth, N. H., was made between September 10 and October 3, 1934. Wax impressions were not made at this inspection. The plates were photographed, washed, scrubbed, wire brushed, sandblasted and again photographed. It is not considered that conclusions as to relative merits of the plates should be drawn at this time. The inspection of the plates at the U. S. Naval Station, Key West, Fla., was made February 4 to 7, 1935. Wax impressions were not made at this inspection. The plates were scraped, cleaned, sandblasted and photographed. No appreciable progress of corrosion has been noticed for several years and it is not believed that conclusions as to the relative merits of the plates should be drawn at this time.

The crates of copper-bearing and non-copper-bearing steel tubing immersed with the riveted test plates at Portsmouth and Key West have been given the annual inspection concurrently with the riveted plates. It is believed that discussion of the relative merits of these specimens should be deferred until a more advanced stage of corrosion has been reached.

Subcommittee VI on Specifications for Metallic-Coated Products (V. F. Hammel, chairman).—The activities of this subcommittee as related to new specifications or changes in existing standards for metallic-coated materials for which it is responsible have been referred to earlier in this report and are further discussed in its report appended hereto. Further specifications await the completion of development work now under way in Subcommittee VII on Methods of Testing covering (*1*) methods for determining weight of coatings on heavy hardware and on irregularly shaped parts, (*2*) revised methods for carrying out the Preece test, and (*3*) methods for determining the thickness of electroplated coatings.

Subcommittee VII on Methods of Testing (L. W. Hopkins, chairman).—Subcommittee VII has been actively considering suitable modifications of standard procedures for conducting the Preece test. A modified procedure has been worked out and tested comparatively in several laboratories. It is expected that a revision of this test method will be approved shortly by the subcommittee. Work is also under way on methods for determining the thickness of electrodeposited coatings, such methods to be suitable for inclusion in standards covering these coatings.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 108, 109 (1932).

Table I.—Report on Total Immersion Tests. Sheets Exposed M

No. 16 Gag

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test			
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Sept. 6, 1929, 921 Days	Oct. 7, 1929,[a] 952 Days	Nov. 7, 1929, 983 Days
AA	Bessemer Steel	A	Non-Copper-Bearing	0.030	0.420	0.085	0.040	0.003	0.012	6			
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.080	0.440	0.080	0.032		0.014	6		1	
II	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.060	0.360	0.091	0.066	0.005	0.254	6			
ZZ3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.078	0.340	0.091	0.036		0.287	6			
BB	Open-Hearth Steel	A	Non-Copper-Bearing	0.058	0.359	0.022	0.049	0.005	0.109	6			
FF	Open-Hearth Steel	A	" " "	0.280	0.500	0.027	0.038	0.010	0.034	6			
OO	Low-Copper Open-Hearth Steel	A	" " "	0.110	0.360	0.008	0.029	trace	0.026	6			3
MM	Open-Hearth Steel, Alan Wood Steel Co.	B	" " "	0.111	0.400	0.010	0.028	0.011	0.053	6			
ZZ4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.047	0.389	0.040	0.027	0.007	0.033	6	418		
GG	Open-Hearth Steel	A	Copper-Bearing	0.290	0.510	0.028	0.039	0.010	0.217	6			
HH	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.069	0.371	0.010	0.026	0.004	0.248	6			
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.087	0.330	0.009	0.019	0.008	0.239	6			
ZZ5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.075	0.390	0.070	0.073		0.257	6			
CC	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.020	0.027	0.005	0.033	0.003	0.078	6			
DD	Low-Copper Pure Iron	A	" " "	0.019	0.025	0.004	0.027	0.003	0.028	6			
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.015	0.021	0.006	0.020	0.005	0.023	6		6	
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.028	0.060	0.009	0.028	0.006	0.030	6		13	11
CCC	Copper-Bearing Pure Iron	A	Copper-Bearing	0.018	0.028	0.005	0.032	0.006	0.262	6			
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.014	0.075	0.006	0.028	0.007	0.250	6			
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.009	0.050	0.008	0.018		0.288	6			
KK	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.100	0.460	0.085	0.039		0.230	6			
EE	Puddled Iron	A	Copper-Bearing	0.033	0.026	0.111	0.019	0.109	0.307	6			
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.050	0.124	0.019	0.210	0.021	6			
										138	1	3	2
	Total Failures to Date										1	4	6

[a] All specimens in the inspection on these dates were sand blasted to facilitate inspection.

PLATE I.
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 35, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

POSED MARCH 1, 1927, IN SEA WATER AT U. S. NAVAL STATION, KEY WEST, FLA.

o. 16 GAGE SHEETS

Failures on Dates of Inspections

Oct. 7, 1929,[a] 952 Days	Nov. 7, 1929, 983 Days	June 6, 1930, 1194 Days	Sept. 6, 1930, 1286 Days	Jan 8, 1931,[a] 1410 Days	Mar. 10, 1931, 1471 Days	Jan. 13, 1932,[a] 1780 Days	Feb. 12, 1932, 1810 Days	Mar. 14, 1932, 1840 Days	July 13, 1932, 1961 Days	Aug. 12, 1932, 1990 Days	Sept. 14, 1932, 2024 Days	Nov. 14, 1932, 2085 Days	Jan. 11, 1933,[a] 2143 Days	Mar. 14, 1933, 2205 Days	Apr. 15, 1933, 2237 Days	May 15, 1933, 2267 Days	June 15, 1933, 2298 Days	July 15, 1933, 2328 Days	Aug. 14, 1933, 2358 Days	Sept. 19, 1933, 2394 Days	Oct. 17, 1933, 2422 Days	Nov. 16, 1933, 2452 Days	Dec. 15, 1933, 2481 Days	Jan. 22, 1934,[a] 2519 Days	Apr. 20, 1934, 2607 Days	June 21, 1934, 2669 Days	July 20, 1934, 2698 Days	Aug. 20, 1934, 2729 Days	Sept. 21, 1934, 2761 Days	Oct. 23, 1934, 2793 Days	Nov. 22, 1934, 2823 Days	Dec. 21, 1934, 2852 Days	Jan. 22, 1935,[a] 2884 Days	Feb. 25, 1935, 2918 Days
1						1, 13							2	1			2					5		28 4				4						
						201		1		205		204	201		10	202		206						18							15			26
	3		417	13	2	11 417, 419	10			419	418	9	6					10				11					8	3	7		21		27 7	20
						501									1		4			501		503		22 13, 15 505				26		16		502, 502		
6 13	11	24		21			32	12															2					11, 13					25	
												18					8				1, 34			13										
						3			6										16	23		20			7									
																		1						2, 13										
				1									6										2	2	2	6								
3	2	1	1	3	1	8	2	2	1	2	1	3	4	1	2	1	3	3	1	2	2	4	2	11	2	1	1	5	1	1	2	2	3	2
4	6	7	8	11	12	20	22	24	25	27	28	31	35	36	38	39	42	45	46	48	50	54	56	67	69	70	71	76	77	78	80	82	85	87

TABLE II.—REPORT ON TOTAL IMMERSION TESTS. SHEETS EXPOSED MAR

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test					
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Dec. 4, 1929,[a] 1003 Days	Feb. 5, 1930, 1066 Days	Mar. 1, 1930, 1090 Days	May 1, 1930, 1151 Days	Jan. 5, 1931,[b]
AA	**Bessemer Steel**..	A	Non-Copper-Bearing	0.053	0.420	0.087	0.041		0.013	6					
ZZ	**Bessemer Steel, Youngstown Sheet and Tube Co**....................	B	" " "	0.078	0.412	0.100	0.038		0.013	6					
II	**Copper-Bearing Bessemer Steel**....................................	A	Copper-Bearing	0.057	0.390	0.098	0.066		0.247	6					
ZZ2	**Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co**....	B		0.088	0.317	0.092	0.045	0.000	0.276	6					
BB	**Open-Hearth Steel**..	A	Non-Copper-Bearing	0.063	0.338	0.030	0.057	0.078	0.122	6					
FF	**Open-Hearth Steel**..	A	" " "	0.277	0.500	0.027	0.038	0.010	0.034	6					
OO	**Low-Copper Open-Hearth Steel**...................................	A	" " "	0.117	0.377	0.010	0.027	0.005	0.030	6			15		
MM	**Open-Hearth Steel, Alan Wood Steel Co**..........................	B	" " "	0.105	0.420	0.011	0.032	0.005	0.052	6					
ZZ4	**Open-Hearth Steel, Youngstown Sheet and Tube Co**................	B	" " "	0.028	0.392	0.042	0.029		0.028	6					
GG	**Open-Hearth Steel**..	A	Copper-Bearing	0.293	0.506	0.028	0.039	0.010	0.217	6					
HH	**Copper-Bearing Basic Open-Hearth Steel**.........................	A	" "	0.073	0.372	0.015	0.027		0.228	6		32			
TT	**Copper-Bearing Steel, Newport Rolling Mill Co**..................	B	" "	0.076	0.305	0.010	0.020		0.226	6					
ZZ5	**Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.**	B	" "	0.066	0.373	0.056	0.066		0.227	6					
CC	**Low-Copper Pure Iron**...	A	Non-Copper-Bearing	0.020	0.031	0.004	0.033		0.065	6				18	
DD	**Low-Copper Pure Iron**...	A	" " "	0.020	0.034	0.004	0.026		0.028	6	50			35	
SS	**Low-Copper Pure Iron, American Rolling Mill Co**.................	B	" " "	0.014	0.017	0.006	0.023		0.028	6					
XX	**Low-Copper Pure Iron, Inland Steel Co**..........................	B	" " "	0.019	0.053	0.008	0.031		0.027	6					
CCC	**Copper-Bearing Pure Iron**.......................................	A	Copper-Bearing	0.018	0.027	0.005	0.027	0.005	0.221	6					
UU	**Copper-Bearing Pure Iron, Allegheny Steel Co**...................	B	" "	0.013	0.066	0.010	0.033		0.243	6					
VV	**Copper-Bearing Pure Iron, Whitaker-Glessner Co**.................	B	" "	0.016	0.033	0.007	0.022		0.289	6					
KK	**Copper-Bearing Acid Open-Hearth Steel**..........................	A	Copper-Bearing	0.120	0.418	0.085	0.042		0.240	6					
EE	**Puddled Iron**...	A	Copper-Bearing	0.030	0.040	0.124	0.018	0.130	0.334	6					
YY	**Low-Copper Wrought Iron, Youngstown Sheet and Tube Co**........	B	Non-Copper-Bearing	0.030	0.052	0.123	0.018	0.193	0.024	6					7
										138	1	1	1	2	1
	Total Failures to Date..	...	....	......	......	......	......	......	......	....	1	2	3	5	6

[a] All specimens in the inspection on these dates were sand blasted to facilitate inspection.
[b] All specimens in the inspection on this date had been sand blasted on May 27, 1930, and October 15, 1930.
[c] All specimens in the inspection on this date had been sand blasted on April 6, 1931.
[d] All specimens in the inspection on this date had been sand blasted on April 5, 1932.

PLATE II.
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 35, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

ED MARCH 7, 1927, IN SEA WATER AT U. S. NAVY YARD, PORTSMOUTH, N. H.

No. 16 GAGE SHEETS

Failures on Dates of Inspections

May 1, 1930, 1151 Days	Jan. 5, 1931,[b] 1400 Days	Feb. 5, 1931, 1431 Days	Aug. 6, 1931,[c] 1615 Days	Sept. 5, 1931, 1646 Days	Oct. 5, 1931, 1676 Days	Dec. 5, 1931, 1737 Days	Jan. 5, 1932, 1768 Days	Feb. 5, 1932, 1799 Days	July 5, 1932,[d] 1497 Days	Aug. 5, 1932, 1978 Days	Sept. 5, 1932,[a] 2009 Days	Dec. 6, 1932, 2101 Days	Jan. 5, 1933, 2131 Days	Mar. 6, 1933, 2191 Days	Apr. 5, 1933,[a] 2221 Days	June 5, 1933, 2282 Days	Aug. 7, 1933, 2345 Days	Sept. 5, 1933,[a] 2374 Days	Oct. 5, 1933, 2404 Days	Dec. 5, 1933, 2465 Days	Feb. 6, 1934, 2528 Days	Mar. 5, 1934, 2555 Days	Apr. 5, 1934,[a] 2586 Days	May 7, 1934, 2618 Days	June 5, 1934, 2648 Days	July 5, 1934, 2678 Days	Aug. 6, 1934, 2710 Days	Sept. 6, 1934, 2741 Days	Oct 5, 1934,[a] 2770 Days	Nov. 5, 1934, 2801 Days	Dec. 5, 1934, 2831 Days	Jan. 4, 1935, 2861 Days	Feb. 5, 1935, 2893 Days	Mar. 6, 1935,[a] 2922 Days
											31			5				34					8											43, 49 7, 7, 8, 14
																					213		33					38		206	213	43 208		37, 40
		420		33	10	39	32 422	35	422	34	27	11			28			11 40 420	31				10			426	426		48		37	12		42
			21									37, 44						27			510		10	10 507			42 505	40 506			30			11, 12 46
18 35						52	15		42	16			27		25						42	28 29	27 40 40 30			20 47 38	26		24	37			30 28	
											21							37							21									32, 37 49
											26					47												52			57			50
						15											17													22 27				30
	7				8													9		9, 8		9												
2	1	1	1	1	2	3	3	1	2	2	4	3	1	1	2	1	1	7	1	2	3	3	8	2	1	4	4	4	2	4	4	3	2	17
5	6	7	8	9	11	14	17	18	20	22	26	29	30	31	33	34	35	42	43	45	48	51	59	61	62	66	70	74	76	80	84	87	89	106

A special group is now being formed to study the determination of weight of zinc coatings on heavy hardware and on irregularly shaped parts where area determinations are difficult to make.

Subcommittee VIII on Field Tests of Metallic Coatings (R. F. Passano, chairman).—Subcommittee VIII carried out the regular periodic inspection of galvanized sheet specimens exposed at the various locations for the past eight years. In its appended report, the subcommittee provides extensions to the data presented last year, bringing the tests up to date and again presents a very concise picture of the progressive deterioration of these sheet specimens.

An extensive tabulation of inspections of the tests on coated hardware, structural shapes, tubular goods, etc., after an exposure period of 305 weeks is also presented in the appended report.

The Wire Test Committee of this subcommittee has continued its work on getting the tests on wire and wire products under way. This project has advanced steadily and it is hoped that the tests may be begun before the end of 1935. Since the detailed plans of these tests were published last year, no further outline is considered necessary at this time.

Subcommittee X on Embrittlement Investigation (W. G. Kelley, chairman).—The action of this subcommittee in recommending the adoption as standard of the Tentative Recommended Practice for Safeguarding Against Embrittlement of Hot-Galvanized Structural Steel Products and Procedure for Detecting Embrittlement (A 143 - 32 T) is covered earlier in this report. This recommendation was submitted to letter ballot of the subcommittee which consists of 28 members, 25 members returned their ballots, of whom 24 have voted affirmatively, 0 negatively, and 1 marked his ballot "not voting." The subcommittee plans to continue the gathering of further information on the effect of size of shape and type of steel on embrittlement and methods for testing various shapes.

This report has been submitted to letter ballot of the committee, which consists of 127 members; 80 members returned their ballots, of whom 73 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

F. F. FARNSWORTH,
Chairman.

JAMES ASTON,
Secretary.

REPORT OF SUBCOMMITTEE VI ON SPECIFICATIONS FOR METALLIC-COATED PRODUCTS

Since the annual meeting in June, 1934, Subcommittee VI has held one meeting on March 5, 1935, in Philadelphia, Pa., in conjunction with the Spring Group Meetings of A.S.T.M. Committees.

At this meeting the specifications for zinc-coated barbed wire and for fencing galvanized after weaving were discussed. The inclusion of more than one weight of coating in these specifications has been under consideration since March, 1933. It now appears probable that two heavier weights of coating will be included. Consideration will also be given to the preparation of specifications for barbed wire galvanized after weaving, a matter that has also been held up since 1933, pending the decision on heavier weights of coating. Final development of these specifications will probably be postponed until the early results, at least, are obtained from the wire exposure tests now being started. For the further development of these specifications, closer cooperation with the American Railway Engineering Association is being arranged and a representative of the farm interests has been appointed to this subcommittee from the membership of the American Society of Agricultural Engineers.

Since the Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 32 T) and for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 32 T) carry somewhat lighter weights of coating than the Standard Specifications for Zinc-Coated (Galvanized) Iron or Steel Barbed Wire (A 121 – 30) and for Zinc-Coated (Galvanized) Iron or Steel Farm-Field and Railroad Right-of-Way Wire Fencing (A 116 – 30), it appeared inadvisable to retain the tentative specifications since future development will probably be in the other direction. It was, therefore, decided to recommend, subject to letter ballot approval of the subcommittee, the withdrawal of the Tentative Specifications A 121 – 32 T and A 116 – 32 T. This recommendation was submitted to letter ballot of the subcommittee which consists of 57 members; 51 members returned their ballots, of whom 37 have voted affirmatively and 0 negatively.

As the essential features of the Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 30) have been incorporated in the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A 90 – 33), it was decided to recommend the withdrawal of the Standard Methods A 110 – 30. The results of the letter ballot vote on this question were 45 affirmative and 0 negative.

The Standard Specifications A 121 – 30 and A 116 – 30 refer to the older nomenclature used in Methods A 110 – 30, so it was decided to recommend editorial changes in the requirements as to weight and uniformity of coating so as to clarify the specifications. The several specifications in which reference is made to Methods A 110 will also be revised editorially to refer to the latest Standard Methods A 90 - 33.

The sub-subcommittee appointed in 1931 to cooperate with a committee of the American Electro-Platers' Society presented for approval the three following specifications for electrodeposited coatings.

Tentative Specifications for Electrodeposited Coatings of Zinc on Steel
Tentative Specifications for Electrodeposited Coatings of Cadmium on Steel
Tentative Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel

It was decided to recommend, subject to letter ballot approval of the subcommittee, the approval as tentative of these three specifications as appended hereto.[1] These recommendations were submitted to letter ballot of the subcommittee which consists of 57 members, the results being as follows: Specifications for Coatings of Zinc, 36 affirmative and 0 negative; Specifications for Coatings of Cadmium, 32 affirmative and 0 negative; Specifications for Coatings of Nickel and Chromium, 28 affirmative and 1 negative.

In addition to the above projects, the following developments are expected in the near future:

1. Changes in the Standard Methods A 90 - 33 as Subcommittee VII on Methods of Testing develops stripping methods for galvanized hardware and completes its studies of the Preece test.

2. Preparation of specifications covering:

(*a*) The technique of preparing specimens for and determining by microscopic examination the thickness of electroplated coatings.

(*b*) Stripping or "dropping" methods of finding the thickness of electroplated coatings.

3. Revision of the Standard Specifications for Zinc-Coated (Galvanized) Sheets (A 93 - 27).

In view of the election of Mr. F. F. Farnsworth, former chairman of this subcommittee, to the chairmanship of Committee A-5, Mr. V. H. Hammel has been elected to the chairmanship of this subcommittee in his stead.

Respectfully submitted on behalf of the subcommittee,

V. F. HAMMEL,
Chairman.

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[1] See pp. 682, 684 and 686.—ED.

REPORT OF SUBCOMMITTEE VIII ON FIELD TESTS OF METALLIC COATINGS

Subcommittee VIII has held one general meeting since the 1933 annual meeting of the Society. Progress has been made in its atmospheric test program and it is the intention of the present report to record this progress.

GALVANIZED SHEETS

The Special Committee on Inspection of Galvanized Sheets has continued the inspection of the tests at all five locations at regular intervals as indicated in previous reports.

It will be recalled that the coatings on all of the galvanized sheets exposed on the Altoona test rack had failed locally and were reported in detail in the 1934 annual report.[1] The progressive development of rust on the zinc-coated sheets at this location is indicated by the curves of Fig. 1 (*a*). All sheets coated with less than 2.00 oz. per sq. ft. of zinc are 100 per cent rusted. The 2.00-oz. coatings are almost completely gone and the surfaces of the 2.50-oz. coatings are about 75 per cent rusted.

All of the galvanized coatings on the Brunot Island (Pittsburgh), Pa., test rack have now failed locally, the last 2.50-oz. coating having failed in October, 1934, after 8.52 yr. The time at which initial failures were observed on the coatings exposed at Brunot Island are summarized in Table I. The progressive development of rust on the zinc-coated sheets at Brunot Island is indicated by the curves of Fig. 1 (*b*). It will be seen that the 1.50-oz. coatings and the lighter classes are practically 100 per cent rusted. The 2.00-oz. coatings are more than 75 per cent rusted while the 2.50-oz. coatings are less than 50 per cent rusted.

At Sandy Hook, N. J., four of the 2.00-oz. coatings now show local failure as indicated by rust spots, and four additional 1.50-oz. coatings show local failure (making a total of 17 in this class to date). At this location all 0.75-oz. coatings and all 1.25-oz. coatings have failed locally, but none of the 2.50-oz. coatings have as yet failed. The time of initial failure of the coatings at this location is summarized to date in Table II. The progressive development of rust on the sheets at Sandy Hook is indicated by the curves of Fig. 1 (*c*). It will be seen that no coating class at this location is 100 per cent rusted at the present time.

On the State College, Pa., test rack, only one of the light-coated sheets has shown a rust spot and this has been noted in previous reports.

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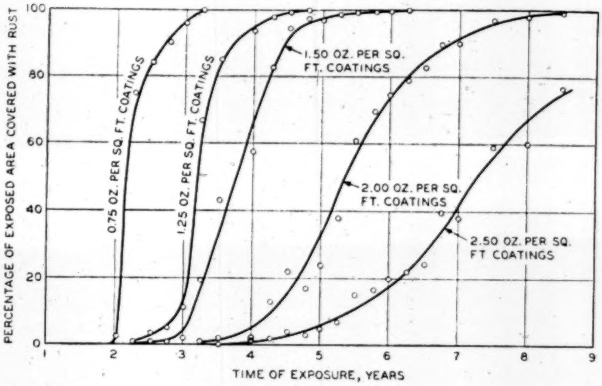
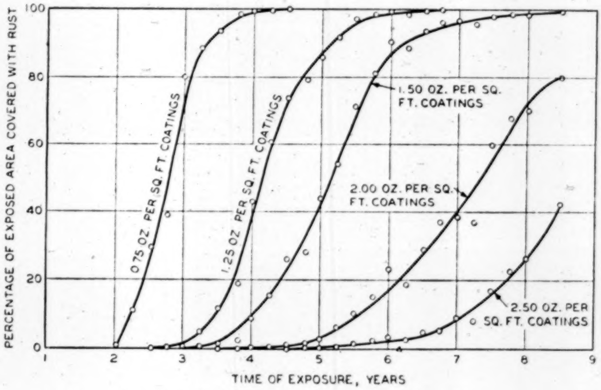
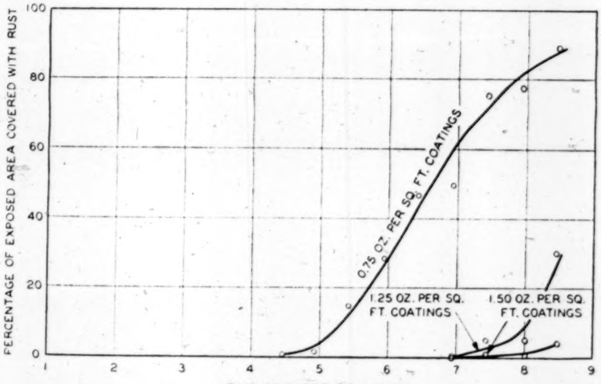
[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 159 (1934).



(*a*) At Altoona, Pa.



(*b*) At Brunot Island, Pittsburgh, Pa.



(*c*) At Sandy Hook, N. J.

FIG. 1.—Progressive Development of Rust on Zinc-Coated Sheets.

TABLE I.—RECORD OF COATING FAILURES ON BRUNOT ISLAND, PITTSBURGH, PA., TEST RACK.[a] SHEETS EXPOSED APRIL 21, 1926.

Description	Number of Specimens in Test	Sept. 27, 1927, 1.43 years	Apr. 30, 1928, 2.03 years	July 26, 1928, 2.27 years	Oct. 29, 1928, 2.53 years	July 22, 1929, 3.25 years	Oct. 28, 1929, 3.52 years	Feb. 11, 1930, 3.81 years	Apr. 21, 1930, 4.00 years	July 27, 1930, 4.27 years	Oct. 30, 1930, 4.52 years	Feb. 4, 1931, 4.79 years	Apr. 20, 1931, 5.00 years	July 20, 1931, 5.25 years	Oct. 19, 1931, 5.50 years	Jan. 29, 1932, 5.78 years	July 25, 1932, 6.26 years	Apr. 24, 1933, 7.01 years	July 24, 1933, 7.26 years[a]	Oct. 29, 1934, 8.52 years	Total Number of Failures	Average Life in Years
No. 16 Gage, 2.50 oz. per sq. ft.....	12	none	none	none	none	none	none	none	none	1	none	2	1	4	3	1	..	..	..	..	12	5.18
No. 22 Gage, 2.50 oz. per sq. ft.....	18	none	none	none	none	none	none	none	1	1	1	none	none	4	4	1	2	1	1	2	18	5.86
No. 22 Gage, 2.00 oz. per sq. ft.....	18	none	none	none	none	none	1	none	2	3	6	3	none	1	none	2	..	..	..	..	18	4.59
No. 22 Gage, 1.50 oz. per sq. ft....	18	none	none	none	none	10	3	3	1	1	..	..	..	..	..	..	..	..	..	..	18	3.49
No. 22 Gage, 1.25 oz. per sq. ft.....	18	none	none	none	2	16	..	..	..	..	..	..	..	..	..	..	..	..	..	..	18	3.17
No. 22 Gage, 0.75 oz. per sq. ft.....	14	none	5	9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	14	2.18
No. 28 Gage, 0.75 oz. per sq. ft....	10	none	2	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	2.22
	108	none	7	17	2	26	4	3	4	6	7	5	1	9	7	4	2	1	1	2		
Total Failures to Date.........	......	none	7	24	26	52	56	59	63	69	76	81	82	91	98	102	104	105	106	108	108	

[a] Columns representing intermediate inspections at which no new failures were observed have been omitted in this tabulation. For similar record of coating failures on Altoona, Pa., test rack, see Table I, report of Subcommittee VIII of Committee A-5, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 150 (1933).

The sheets exposed at Key West, Fla., were inspected on March 8, 1935, after 8.74 yr. It was found that none of the coatings had failed and that the appearance was similar to that described in the previous reports.

TABLE II.—RECORD OF COATING FAILURES ON SANDY HOOK, N. J., TEST RACK.[a] SHEETS EXPOSED MAY 20, 1926.

Description	Number of Specimens in Test	April 24, 1930 3.93 years	Oct. 30, 1930, 4.45 years	Apr. 22, 1931, 4.93 years	Oct. 21, 1931, 5.42 years	Apr. 27, 1932, 5.94 years	Oct. 26, 1932, 6.45 years	Apr. 26, 1933, 6.93 years	Oct. 25, 1933, 7.43 years	Oct. 31, 1934, 8.45 years	Total Number of Failures	Average Life in Years
No. 16 Gage, 2.50 oz. per sq. ft.	10	none	none	none	none	none	none	none	none	none	none	....
No. 22 Gage, 2.50 oz. per sq. ft.	18	none	none	none	none	none	none	none	none	none	none	....
No. 22 Gage, 2.00 oz. per sq. ft.	18	none	none	none	none	none	none	none	none	4	4	....
No. 22 Gage, 1.50 oz. per sq. ft.	18	none	none	none	none	none	1	3	9	4	17	(7.64)[b]
No. 22 Gage, 1.25 oz. per sq. ft.	18	none	none	none	1	3	3	4	7	....	18	6.80
No. 22 Gage, 0.75 oz. per sq. ft.	14	none	10	1	2	none	1	..	..	....	14	4.77
No. 28 Gage, 0.75 oz. per sq. ft.	10	none	6	1	2	none	1	..	..	....	10	4.89
	106	none	16	2	5	3	6	7	16	8	..	
Total Failures to Date.....	..	none	16	18	23	26	32	39	55	63	63	

[a] Columns representing intermediate inspections at which no new failures were observed have been omitted in this tabulation.

[b] Figures shown in parentheses are not to be considered as final.

TABLE III.—TIME IN YEARS FOR PERFORATIONS OF NO. 22 GAGE, BLACK SHEETS.[a]

Identification	Class of Material	Average Chemical Composition									Brunot Island, Pittsburgh, Pa.	Altoona, Pa.	Key West, Fla.	Sandy Hook, N. J.	State College, Pa.
		Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent	Silicon, per cent	Copper, per cent	Nickel, per cent	Chromium, per cent	Molybdenum, per cent					
R	Open-Hearth Iron.......	0.011	0.021	0.004	0.018	0.004	0.032	0.023	[d]	0.004[b]	2.03	4.27	3.62	5.94	—
V	Open-Hearth Iron.......	0.018	0.053	0.005	0.032	0.004	0.051	0.045	[d]	0.007[b]	2.27	4.27	3.62	4.93	—
U	Open-Hearth Iron.......	0.015	0.020	0.004	0.024	0.005	0.087	0.106	[d]	0.009[b]	2.53	4.27	3.62	5.42	—
N	Open-Hearth Iron.......	0.013	0.057	0.007	0.029	0.003	0.167	0.057	[d]	0.004[b]	3.00	7.51	3.62	5.94	—
T	Open-Hearth Iron.......	0.016	0.157	0.007	0.028	0.004	0.228	0.073	[d]	0.004[b]	—	8.52	3.62	6.45	—
Y	Open-Hearth Steel......	0.028	0.346	0.067	0.050	0.005	0.029	0.003[b]	0.013	[c]	2.03	2.03	2.62	3.45	—
S	Open-Hearth Steel......	0.040	0.488	0.072	0.041	0.003	0.051	0.006[b]	0.094	[c]	3.25	—	3.62	—	—
C	Open-Hearth Steel......	0.066	0.458	0.053	0.045	0.003	0.222	0.003[b]	0.000[b]	[c]	—	—	5.73	—	—
K	Open-Hearth Steel......	0.023	0.460	0.066	0.045	0.003	0.268	0.023[b]	0.031	[c]	—	—	4.58	—	—
W	Wrought Iron...........	0.021	0.048	0.143	0.019	0.210	0.025	0.020[b]	[d]	0.003[b]	3.00	5.00	3.62	4.93	—

[a] Blanks in table represent sheets that have not failed as yet. The material has been under observation for 8.75 years.

[b] Average of determinations in one laboratory.

[c] Less than 0.003 per cent; results of one laboratory.

[d] Less than 0.006 per cent; results of one laboratory.

Nine of the twenty-four 0.75-oz. coated sheets now show slight "yellowing" at local spots. Five of these nine showed only a trace of "yellow" discoloration. The maximum area on any one sheet which had reached this condition was estimated at 5 per cent.

Figure 2 shows a relationship between weight of coating and the time at which rust appears on the zinc-coated sheets exposed at Brunot Island. A similar relationship was shown last year for the Altoona location. In Fig. 2, the effect of the weight of coating on the time required for the appearance of rust at Altoona is shown by a broken line for comparison with a similar relationship shown for Brunot Island.

The results now available confirm the tentative conclusions published last year, namely, that at a given location the amount of protection is substantially in accord with the weight of coating and that the same weight of coating gives quite different amounts of protection at different locations.

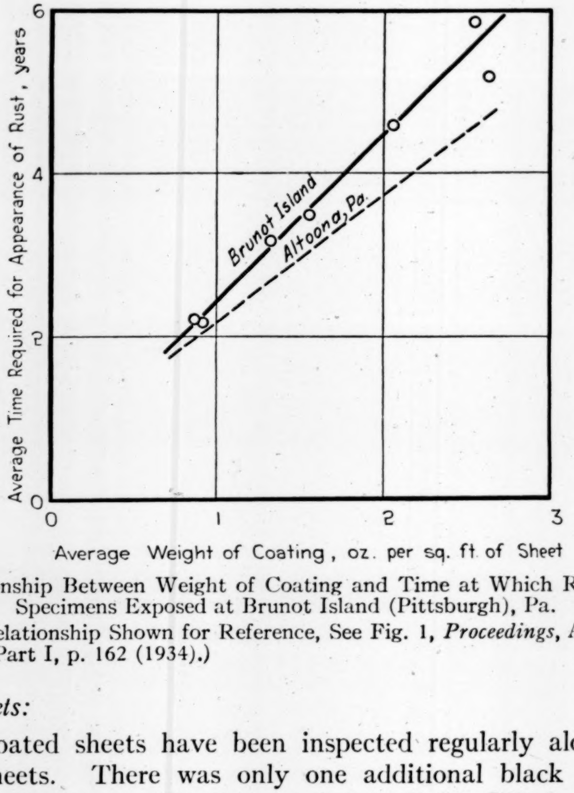


FIG. 2.—Relationship Between Weight of Coating and Time at Which Rust Appears on Specimens Exposed at Brunot Island (Pittsburgh), Pa.

(Altoona Relationship Shown for Reference, See Fig. 1, *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 162 (1934).)

Uncoated Sheets:

The uncoated sheets have been inspected regularly along with the galvanized sheets. There was only one additional black sheet failure found during the year. This is recorded in Table III along with those which had previously been observed.

COATED HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC.

A Special Committee on Inspection of Coated Hardware, Structural Shapes, Tubular Goods, etc., under the chairmanship of Mr. W. L. Maucher, has made several inspections during the past two years, the results of which are shown in Table IV. These tables cover the following eight types of coating which were applied to the various shapes in 1928 by commercial operations:

1. Hot-dipped zinc
2. Electrodeposited zinc
3. Sherardized (zinc) applied in gas-heated drum
4. Sherardized (zinc) applied in electrically heated drum
5. Electrodeposited cadmium
6. Hot-dipped aluminum
7. Hot-dipped lead (Amaloy)
8. Parkerized

It will be noted that four of these are zinc coatings representing as many processes.

The accompanying Table IV is an extension of Table VII of the 1933 report[1] and Table V of the 1931 report[2] of Subcommittee VIII. In the 1933 report,[1] the data available were summarized. The present tabulation shows that in most cases the proportion of the exposed surface of the specimens covered with rust has increased. The additional rusting does not appear to have altered previous indications of the data.

The question has been raised on occasion whether the weight of coating on certain items was known definitely and whether the commercial methods of coating as now practiced are not an improvement of commercial methods of coating as practiced in 1928 when the present test specimens were coated. In light of these two grounds for uncertainty, the Advisory Committee A-5 has authorized an extension of these tests on a limited number of shapes coated to definite weight-of-coating classes by a limited number of processes. The subcommittee was of the opinion in 1933 that the service given by a metallic coating, of zinc, for example, depended on the weight of coating and its uniformity rather than on the method by which it was applied. Greater knowledge of the weight of coating on the test specimens and careful selection of specimens to fall in definite weight-of-coating classes should assist materially in the interpretation of the broad range of data which have been accumulated from the first experiment on coated hardware, structural shapes, tubular goods, etc.

This report of Subcommittee VIII has been submitted to letter ballot of the subcommittee, which consists of 42 members; 15 members returned their ballots, all of whom have voted affimatively.

Respectfully submitted on behalf of the subcommittee,

R. F. PASSANO,
Chairman.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 33, Part I, p. 154 (1933).
[2] *Proceedings,* Am. Soc. Testing Mats., Vol. 31, Part I, p. 183 (1931).

TABLE IV.—REPORT ON INSPECTIONS OF METALLIC COATINGS ON HARDWARE, STRUCTURAL SHAPES, TUBULAR GOODS, ETC. EXPOSED TO ATMOSPHERE ON TEST RACKS AT FIVE LOCATIONS.

Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.				Exposure at Altoona, Pa.				Expoure at State College, Pa.				Exposure at Sandy Hook, N. J.				Exposure at Key West, Fla.
		4/24/33 225 weeks	10/23/33 251 weeks	4/23/34 277 weeks	10/29/34 304 weeks	4/25/33 226 weeks	10/23/33 252 weeks	4/24/34 278 weeks	10/30/34 305 weeks	4/25/33 225 weeks	10/24/33 251 weeks	4/24/34 277 weeks	10/30/34 304 weeks	4/26/33 226 weeks	10/25/33 252 weeks	4/25/34 278 weeks	10/31/34 305 weeks	2/7/34 263 weeks
3 BY 3 BY $\frac{5}{16}$-IN. PLAIN STEEL ANGLES																		
Electro Galvanized	0.52	71R	74R	68R	80Ra	32R	51R	56R	71R	Tr.R	Tr.R Tr.Y	Tr.R	Tr.R	<10Ra	14Ra	10Ra	17Ra	Tr.R
Hot Dip Galvanized	2.52	0	0	0	0	0	Tr.Y	0d	Tr.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.89	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.09	First R in 16 weeks.		All R in 120 weeks		First R in 17 weeks.		All R in 44 weeks		First R in 16 weeks.		All R in 304 weeks		First R in 17 weeks.		All R in 121 weeks		87R
Electric Sherardized	1.38	100 dark Y edge R	10R 90Y	1R 99Y	10R 45Y	25R 75Y	12R 25Y	10R 93Y	10R 40Y	100Y	50Y	100Y	50Y	30Y	<10R 40Y	100Y	Tr.R 50Y	15Y
Lead Plated	....	38R	29R	26R 2Y	10R 13Y	0d	Tr.Y	0d	<10R	71R*	81R*	56R	70R*	58R*	58R <10Y	48R*	60R*	53R*
3 BY 3 BY $\frac{5}{16}$-IN. COPPER-BEARING STEEL ANGLES																		
Electro Galvanized	0.37	48R	61R	60R	66Ra	62R Tr.Y	67R	76R	71R	Tr.Ra	Tr.R Tr.Y	Tr.R	Tr.R	Tr.Ra	13R	<10Ra	<10Ra	0
Hot Dip Galvanized	2.88	0	0	0	0	0	Tr.Y	0d	Tr.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.82	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.24	First R in 16 weeks.		All R in 120 weeks		First R in 17 weeks.		All R in 69 weeks		30R	43R	38Ra	51R	58R	94R Tr.Y	95R	96R	25Ra
Electric Sherardized	1.44	100Y	5R 90Y	100Y	<10R 47Y	20R 67Y	24R 23Y	20R 63Y	24R 28Y	100Y	100Y	100Y	100Y	23Y	<10R 76Y	100Y	Tr.R 50Y	40Y
Lead Plated	....	57R	37R	35R	16R	0d	<10Y	0d	<10R	63R*	66R*	53R*	67R*	66R*	63R <10Y	64R*	70R*	65R
2 BY 1½ BY $\frac{3}{16}$-IN. PLAIN STEEL ANGLES																		
Electro Galvanized	0.53	First R in 43 weeks.		All R in 304 weeks		75R	87R	80R	99R	13Ra	13Ra	13Ra	21Ra	20Ra	31Ra	40Ra	51R	<10Ra
Electro Galvanized	0.50	First R in 95 weeks.		All R in 277 weeks		First R in 96 weeks.		All R in 252 weeks		Tr.Ra	Tr.R	2R	Tr.Ra Tr.Ya	22Ra	43R	53Ra	62R	<10R
Hot Dip Galvanized	3.24	0d	0	0	0	0	0d	sl.Y	sl.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.75	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	0.43	First R in 16 weeks.		All R in 68 weeks		First R in 17 weeks.		All R in 69 weeks		40Ra	46R	43Ra	58Ra	80R	91R	93R	98R	30R
Electric Sherardized	1.21	75R	90R	93R	95R	First R in 96 weeks.		All R in 252 weeks		100Y	Tr.R 98Y	1R 99Y	27R 59Y	<10R 47Y	38R 28Y	55R <10Y	78R 10Y	10R
Lead Plated	....	43R*	31R*	56R*	56R*	0d	Tr.R	0d	32R	48R*	52R	50R*	55R*	45R*	42R	40R	47R*	<10R
2 BY 1½ BY $\frac{3}{16}$-IN. COPPER-BEARING STEEL ANGLES																		
Electro Galvanized	0.70	83R	84R	92R	97R	76R	83R	86R	93R	0	sl.R	<10Ra	<10Ra	20Ra	27Ra	26Ra	30R	<10Ra
Electro Galvanized	0.76	73R	82R	80R	87R	70Ra	87R	80R	91R	<10Ra	<10Ra	<10Ra	<10R	20Ra	25Ra	26Ra	30R	<10Ra
Hot Dip Galvanized	2.75	0	0	0	Tr.Y	0	Tr.Y	sl.Y	sl.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.50	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	0.50	First R in 16 weeks.		All R in 68 weeks		First R in 17 weeks.		All R in 69 weeks		16Ra	25R	35Ra	39R	81R	88R	92R	97R	25R
Electric Sherardized	1.15	100R	94R	88R	99R	First R in 120 weeks.		All R in 252 weeks		First R in 43 weeks.		All R in 68 weeks		<10R 45Y	54R 46Y	56R	76R <10Y	All R in 52 weeks
Gas Sherardized	**0.17**	First R in 16 weeks.		All R in 68 weeks		First R in 17 weeks.		All R in 44 weeks		....	....	....	....	First R in 44 weeks.		All R in 44 weeks		All R in 52 weeks
Lead Plated	....	23R*	21R*	33R*	33R*	0d	Tr.R	0d	27R	58R*	57R*	60R*	64R*	24R*	24R	16R	27R*	22R
2-IN. DIAMETER TUBULAR GOODS																		
Electro Galvanized	1.58	0	0	0	Tr.R	0	0	0	Tr.R sl.Y	0	Tr.R Tr.Y	0	0	0	0	0	0	0
Hot Dip Galvanized	2.51	0	<10Y	<10Y	11R	sl.Y	<10Y	<10Y										

2-IN. DIAMETER TUBULAR GOODS																		
Electro Galvanized		1.58	0	0	0	Tr.R	0	0	0	Tr.R sl.Y	0	Tr.R Tr.Y	0	0	0	0	0	0	0
Hot Dip Galvanized		2.51	0	<10Y	<10Y	11R	sl.Y	<10Y	<10Y	Tr.R 16Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum		4.73	0	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated		0.23	First R in 16 weeks.		All R in 95 weeks		First R in 17 weeks.		All R in 69 weeks		20R	25R	26R	36R	90R	93R	97R	99R	<10R
Cadmium Plated		0.10	First R in 16 weeks.		All R in 68 weeks		First R in 17 weeks.		All R in 69 weeks		43R	44R	53R	59R	First R in 44 weeks.		All R in 278 weeks		30R
Electric Sherardized		0.29	First R in 43 weeks.		All R in 120 weeks		First R in 44 weeks.		All R in 121 weeks		46R 24Y	24R 43Y	35R	70R	First R in 96 weeks.		All R in 252 weeks		25R 75Y
Electric Sherardized		0.85	First R in 43 weeks.		All R in 120 weeks		First R in 44 weeks.		All R in 121 weeks		52R 29Y	40R 29Y	40R	74R	First R in 96 weeks.		All R in 226 weeks		95Y
Gas Sherardized		0.66	<10R	22R	25R	43R	13R	41R	40R	78R	100Y	50Y	0d	50Y	100Y	50Y	100Y	51Y	90Y
Lead Plated		....	13R*	19R*	40R*	23R*	0d	0d	0d	12Y	....	65R*	....	81R*	35R*	30R*	32R*	45R*	27R
1-IN. DIAMETER TUBULAR GOODS																		
Electro Galvanized		1.62	0	<10Y	0	<10Y	0	0	1R	sl.Y	Rack Damaged Specimens Mixed				Rack Damaged Specimens Mixed				0
Hot Dip Galvanized		1.83	50Y	80Y	100Y	<10R 95Y	88Y	96Y	90Y	60R 32Y									0
Hot Dip Aluminum		1.83	0	0d	0d	0d	0d	0d	0d	10Y									<10Y
Cadmium Plated		0.30	First R in 16 weeks.		All R in 95 weeks		First R in 17 weeks.		All R in 96 weeks										93R
Cadmium Plated		0.18	First R in 16 weeks.		All R in 120 weeks		First R in 17 weeks.		All R in 96 weeks										0
Electric Sherardized		0.42	First R in 16 weeks.		All R in 120 weeks		First R in 17 weeks.		All R in 120 weeks										95R
Electric Sherardized		0.92	12R	53R 46Y	28R	94R	32R	51R	50R	76R 10Y									40Y
Gas Sherardized		0.72	Tr.R	46R	43R	59R	25R	54R	60R	61R 18Y									100Y
Calorized		....	0	0d	0d	0d	0d	0d	0d	10Y									50R
Lead Plated		....	<10R	13R*	25R*	13R*	0d	<10Rs	0d	<10Rs 25Y									50Y 22R
Amaloy		....	33R	41R*	40R*	43R*	0d	0d	0d	32R 20Y									13R
FORGED STEEL TOWER FITTING																		
Electro Galvanized	Bolt Nut Clamp	0.31 0.54 1.15	86R	88R	90R	93R	85R	93R	90R	95R	0	0	0	0	0	<10R	sl. R	<10R	<10R
Electric Galvanized	Bolt Nut Clamp	0.02 0.01 0.46	73R	74R	76	80R	95R	98R	96R	91R	0	Tr.R	0	Tr.R	<10R	13R	11R	20R	0
Hot Dip Galvanized		2.67	30Y	40Y	30Y	<10R 30Y	45Y	Tr.R 33Y	80Y	<10R 50Y	0	0	0	0	0	0	0	0	10R
Hot Dip Galvanized		1.53	50Y Tr.R	50Y <10R	33Y <10R	44R <10Y	55Y	20R 57Y	Tr.R 100Y	37R 20Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum		....	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0d	0	0	<10R 43Y
Cadmium Plated		1.40	First R in 16 weeks.		All R in 120 weeks		First R in 17 weeks.		All R in 121 weeks		Tr.R	Tr.R	<10R	<10R	First R in 44 weeks.		All R in 252 weeks		18R
Electric Sherardized		0.50	17Y	25Y	10Y	<10R	Tr.R 15Y	17R 51Y	23R 23Y	22R 10Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	100Y	40Y
Gas Sherardized		....	82R	86R	73R	88R	38R	61R	66R	81R	100Y	100Y	100nR*	<10R 93Y	100Y	35R 65Y	50R 50Y	40R 32Y	97R
Parkerized		....	68R	94R	93R	100R	36R	55R	60R	91R	First R in 43 weeks.		All R in 199 weeks		First R in 17 weeks.		All R in 305 weeks		All R in 52 weeks
Cadmium Plated		0.26	First R in 16 weeks.		All R in 146 weeks		First R in 17 weeks.		All R in 69 weeks		Tr.R 33Y	12R 25Y	25R	45R	27R	40R	43R	61R	10R
Lead Plated		....	First R in 16 weeks.		All R in 43 weeks		First R in 17 weeks.		All R in 44 weeks		All R in 16 weeks				All R in 17 weeks				All R in 52 weeks

TABLE IV.—REPORT ON INSPECTIONS OF METALLIC COATINGS, ETC. (*Continued*).

Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.				Exposure at Altoona, Pa.				Exposure at State College, Pa.				Exposure at Sandy Hook, N. J.				Exposure at Key West, Fla.
		4 24 33 225 weeks	10 23 33 251 weeks	4 23 34 277 weeks	10 29 34 304 weeks	4 25 33 226 weeks	10 24 33 252 weeks	4 24 34 278 weeks	10 30 34 305 weeks	4 25 33 225 weeks	10 24 33 251 weeks	4 24 34 277 weeks	10 30 34 304 weeks	4 25 33 226 weeks	10 25 33 252 weeks	4 25 34 278 weeks	10 31 34 305 weeks	2 7 34 263 weeks
¾-in. NIPPLES AND ELLS																		
Electro Galvanized MI { Nipple Ell	1.64 1.55	 0	<10R 10Y	.... Tr.R	<10R <10Y	.... <10R	<10R Tr.Y	.... Tr.R	20R <10Y	 0	 0	 0	 0	Tr.R Tr.Y	.... Tr.Y	.... Tr.Y	Tr.R Tr.Y	 0
Electro Galvanized CI { Nipple Ell	2.02 2.36	 0	.... 10Y	 0	.... Tr.Y	 0	 0	 0	Tr.R Tr.Y	 0	 0	 0	 0	Tr.R Tr.Y	.... Tr.Y	.... Tr.Y	.... Tr.Y	 0
Electro Galvanized MI { Nipple Ell	2.43 2.90	78R	83R	58R 28Y	81R	86R Tr.Y	88R Tr.Y	100R	72R <10Y	0	Tr.R	0	Tr.R Tr.Y	Tr.R Tr.Y	Tr.R	Tr.R Tr.Y	<10R Tr.Y	<10Y ....
Electro Galvanized CI { Nipple Ell	1.82 0.67	66R <10Y	56R <10Y	59R <10Y	57R 11Y	56R Tr.Y	53R 16Y	59R <10Y	64R 15Y	0	0	0	0	Tr.R Tr.Y	Tr.R	Tr.Y	sl.R Tr.Y	<10R 25Y
Hot Dip Galvanized MI	1.82	50Y	67Y	30Y	<10R 67Y	52Y	Tr.R 55Y	80Y	15R 67Y	0	0	0	0	0	0	0	0	0
Hot Dip Galvanized CI	1.44	50Y	63Y	30Y	16R 25Y	19Y	24R 45Y	<10R 58Y	16R 35Y	0	0	0	0	Tr.Y	Tr.Y	0	0	<10Y
Hot Dip Aluminum MI	3.20	0d	0d	0d	0	0d	0d	0d	Tr.R 13Y	25Y	<10R 27Y	0	sl.R sl.Y	Tr.R	Tr.R	<10R 45Y	<10R	25R 17Y
Hot Dip Aluminum CI	2.80	0d	0d	0d	0d	0d	0d	0d	0d	25Y	<10R 20Y	0	sl.R	Tr.R	Tr.R Tr.Y	<10R 45Y	<10R	35R 25Y
Cadmium Plated MI	....	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 69 weeks				17R <10Y	34R 15Y	40R	78R	First R in 96 weeks. All R in 174 weeks				15R
Cadmium Plated CI	....	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				26R <10Y	56R <10Y	47R	86R	First R in 96 weeks. All R in 147 weeks				25R
Cadmium Plated MI	....	52R	85R	75R	81R	First R in 17 weeks. All R in 69 weeks				<10R <10Y	27R 10Y	25R	73R	First R in 96 weeks. All R in 147 weeks				23R
Cadmium Plated CI	....	24R	86R	90R	97R	First R in 17 weeks. All R in 44 weeks				32R <10Y	63R <10Y	36R	86R	First R in 96 weeks. All R in 121 weeks				32R
Electric Sherardized MI	0.63	40R	57R	62R	68R	46R	65R	82R	82R	100Y	50Y	33R 66Y	Tr.R 98Y	100Y	<10R 70Y	20R 80Y	35R 35Y	85Y
Electric Sherardized CI	0.47	First R in 95 weeks. All R in 251 weeks				47R	75R	82R	96R	100Y	100Y	100Y	Tr.R 99Y	10R 47Y	10R 15Y	30R 70Y	53R 15Y	82Y
Gas Sherardized MI	0.78	80R	83R	93R	93R	64R	79R	85R	95R	Tr.R 99Y	100Y	33R 33Y	<10R 72Y	48R 15Y	85R	88R <10Y	72R Tr.Y	60R 40Y
Gas Sherardized CI	0.84	43R	87R	91R	91R	78R	91R	94R	98R	<10R 95Y	20R 38Y	<10R 86Y	33R 46Y	34R <10Y	64R 15Y	40R 60Y	82R sl.Y	90R 10Y
Parkerized MI	....	Tr.R Tr.Y	<10R <10Y	Tr.R <10Y	11R	<10R	35R	47R	38R	49R*	70R	50R*	71R*	32R*	40R*	40R*	76R*	First R in 52 weeks. All R in 162 weeks
Parkerized CI	....	0d	<10R	10Y	12R	sl.R	17R	40R	34R	50Y	70R	30R*	66R*	36R*	40R*	40R*	81R*	First R in 52 weeks. All R in 162 weeks
Electric Sherardized MI	0.75	34R	48Rs	32R	33R	13Y	<10R 56Y	Tr.R <10Y	32R	70Y	50Y	sl.Y	51Y	100Y	100Y	100Y	100Y	75Y
Electric Sherardized CI	0.82	40R	39R	32R	35R	10Y	<10R 42Y	60Y	27R	69Y	50Y	90Y	<10R 46Y	100Y	100Y	100Y	100Y	....
Amaloy MI	....	....	....	....	....	0	0d	0d	<10R	75R*	75R 10Y	80R*	75R*	52R*	80R*	50R*	74R*	70R
Amaloy CI						0d	0d	0d	0.	73R*	78R 10Y	70R*	65R*	60R*	75R*	50R*	74R*	67R

							TOWER CLAMPS												
Electro Galvanized MI	Bolt	0.31	48R	56R	70R	86R	45R	60R	66R	71R	0	0	0	0	<10R	<10R	<10R	18R	<10R
	Nut	0.54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Clamp	1.15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Electro Galvanized CI	Bolt	0.28	72R	85R	90R	94R	86R	91R	99R	100R	0	0	0	0	Tr.Y	<10R	10R	36R	<10Y
	Nut	0.56	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Electro Galvanized MI	Bolt	0.02	93R	95R	96R	98R	First R in 17 weeks. All R in 200 weeks				20R	27R	<10R	15R	30R	38R	39R	45R	15R
	Nut	0.01	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Clamp	0.46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Electro Galvanized CI	Bolt	0.04	90R	92R	95R	96R	First R in 17 weeks. All R in 200 weeks				20R	27R	<10R	20R	34R	44R	52R	67R	35R
	Nut	0.04	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Clamp	0.74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hot Dip Galvanized MI		1.53	40Y	<10R 34Y	<10R 95Y	21R 13Y	40Y	<10R 85Y	15R 85Y	48R 20Y	0	0	0	0	0	0	0	0	<10Y
Hot Dip Galvanized CI		1.75	20Y	<10R 15Y	Tr.R 13Y	14R <10Y	22Y	<10R 75Y	Tr.R 99Y	14R 18Y	0	0	0	0	0	0	0	0	0
Hot Dip Galvanized MI		2.00	<10Y	<10Y	10Y	Tr.R Tr.Y	<10Y	18Y	20Y	60Y	0	0	0	0	0	0	0	0	0
Hot Dip Galvanized CI		2.38	<10Y	<10R <10Y	30R <10Y	Tr.R Tr.Y	<10Y	10Y	5Y	<10Y	0	0	0	0	0	0	0	0	0
Cadmium Plated MI		0.28	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 69 weeks				24R 15Y	50R	53R	85R	First R in 44 weeks. All R in 147 weeks				18R
Cadmium Plated CI		0.28	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 69 weeks				35R <10Y	80R	80R	91R	First R in 44 weeks. All R in 121 weeks				28R
Cadmium Plated MI		0.15	All R in 16 weeks				All R in 69 weeks				First R in 16 weeks. All R in 173 weeks				First R in 17 weeks. All R in 69 weeks				First R in 52 weeks. All R in 162 weeks
Cadmium Plated CI		0.17	All R in 16 weeks				All R in 69 weeks				First R in 16 weeks. All R in 173 weeks				First R in 17 weeks. All R in 69 weeks				First R in 52 weeks. All R in 162 weeks
Electric Sherardized MI		....	First R in 16 weeks. All R in 68 weeks				First R in 44 weeks. All R in 278 weeks				65R 35Y	90R 5Y	90R	92R	First R in 17 weeks. All R in 69 weeks				All R in 52 weeks
Electric Sherardized CI		1.82	0 Flaking	50R	25R	85R	0d	40R	10R	62R	70Y	50Y	sl.Y	75Y	87R	90R	60R 40Y	95R	<10R 70Y
Gas Sherardized MI		0.50	First R in 95 weeks. All R in 251 weeks				Tr.Y	63R	13R	65R	100Y	25R 75Y	100Y	25R 75Y	First R in 174 weeks. All R in 226 weeks				37Y
Gas Sherardized CI		0.63	49R	97R	90R	98R	53R	90R	56R	85R	66R 34Y	76R 5Y	30R 33Y	75R 25Y	64R <10Y	80R	60R	97R	First R in 52 weeks. All R in 162 weeks
Parkerized MI		....	First R in 43 weeks. All R in 143 weeks				50R	100R*	56R	87R	100R	100R	20R	73R*	All R in 44 weeks				All R in 52 weeks
Parkerized CI		....	24R	25R	25R	41R	15R	12R	<10R	<10R	55R* 45Y	100R	10R*	41R	87R*	75R 25Y	23R*	100R	All R in 52 weeks
Hot Dip Aluminum MI		3.16	0	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10R
Hot Dip Aluminum CI		2.51	0	0d	0d	0d	Tr.R	Tr.R	0d	0d	0	0	0	0	0	0	0	0	<10R
Amaloy MI		....	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 121 weeks				85R*	100R*	50R*	100R*	All R in 17 weeks				First R in 52 weeks. All R in 102 weeks
Amaloy CI		....	First R in 16 weeks. All R in 120 weeks				83R	100R	80R*	83R*	80R*	100R*	40R*	58R	75R*	75R*	70R*	100a*	First R in 52 weeks. All R in 152 weeks

MI—indicates malleable iron base metal.
CI—indicates cast iron base metal.

TABLE IV.—REPORT ON INSPECTIONS OF METALLIC COATINGS, ETC. (*Continued*).

Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.				Exposure at Altoona, Pa.				Exposure at State College, Pa.				Exposure at Sandy Hook, N. J.				Exposure at KeyWest, Fla.
		4/24/33 225 weeks	10/23/33 251 weeks	4/23/34 277 weeks	10/29/34 304 weeks	4/25/33 226 weeks	10/24/33 252 weeks	4/24/34 278 weeks	10/30/34 305 weeks	4/25/33 225 weeks	10/24/33 251 weeks	4/24/34 277 weeks	10/30/34 304 weeks	4/26/33 226 weeks	10/25/33 252 weeks	4/25/34 278 weeks	10/31/34 305 weeks	2/7/34 263 weeks
1½ BY 1½ BY ⅛-IN. PLAIN STEEL ANGLES																		
Electro Galvanized	0.47	64R	78R	80R	90R	80R	83R	83R	88R	<10Ra	<10R	10Ra	20Ra	20Ra	27Ra	24Ra	32Ra	<10R
Electro Galvanized	1.09	28R	73R	85R	92R	65Ra	75R	87R	88R	0	0	0	0	<10Ra	<10Ra	<10Ra	17Ra	Tr.Y
Hot Dip Galvanized	3.16	0	0	0	Tr.Y	0	<10Y	<10Y	sl.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.89	0	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	0.12	First R in 95 weeks. All R in 199 weeks				First R in 17 weeks. All R in 69 weeks				19Ra	32R	30Ra	52Ra	First R in 17 weeks. All R in 226 weeks				20R
Electric Sherardized	0.14	First R in 43 weeks. All R in 68 weeks				74R	81R	83R	91R	38Ra	35R	33R	36R	21R	78R	73R	87R	100Y
Gas Sherardized	....	First R in 225 weeks. All R in 225 weeks				First R in 17 weeks. All R in 69 weeks				First R in 43 weeks. All R in 146 weeks				First R in 44 weeks. All R in 96 weeks				First R in 52 weeks. All R in 162 weeks
Lead Plated	....	<10R	<10R*	15R*	<10R	Tr.Y	<10Y	sl.Y	sl.R	28R	34R	35R*	30R*	24R*	26R <10Y	30R*	37R*	....
1½ BY 1½ BY ⅛-IN. COPPER-BEARING STEEL ANGLES																		
Electro Galvanized	0.76	86R	93R	96R	98R	95R	96R	100R	....	Tr.Ra	Tr.R	Tr.R	Tr.R	18Ra	24Ra	23Ra	31Ra	15R
Electro Galvanized	0.47	94R	97R	100R	....	87R	97R	100R	....	0	Tr.Y	Tr.Y	Tr.R	sl.Ra	<10Ra	11Ra	25Ra	0
Hot Dip Galvanized	3.20	0	<10Y	0	0	0	0d	<10Y	<10Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	1.11	0	0	0d	0d	0d	<10R	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.65	67R	74R	100R	....	First R in 17 weeks. All R in 96 weeks				20Ra	20R	30R	37Ra	84R	87R	88R	91R	<10Y
Electric Sherardized	....	....	....	....	....	77R	82R	70R	74R	100Y	100Y	100Y	Tr.R	Tr.R	42R	55R	72R	10R
Gas Sherardized	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	<10R
Lead Plated	....	sl.R	0d	<10R*	<10R	0d	0d	0d	<10R	42R*	48R*	43R	54R*	33R*	34R	31R*	28R	15R
NO. 14 BY 2½-IN. PLAIN STEEL FLATS																		
Electro Galvanized	0.45	First R in 68 weeks. All R in 199 weeks				First R in 96 weeks. All R in 200 weeks				0	0	0	0	69R	82R	90R	96R	0
Electro Galvanized	0.70	<10R	13R	30R	54R	0d	11R	<10R	61R	0	0	0	0	0	0	0	0	0
Hot Dip Galvanized	3.16	Tr.Y	sl.Y	10Y	Tr.R Tr.Y	0	Tr.Y	<10Y	Tr.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.89	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	....	First R in 43 weeks. All R in 68 weeks				First R in 17 weeks. All R in 44 weeks				<10R	13R	13R	21R	First R in 69 weeks. All R in 200 weeks				10R
Electric Sherardized	0.58	First R in 43 weeks. All R in 199 weeks				First R in 44 weeks. All R in 226 weeks				<10R 82Y	<10R 92Y	<10R 96Y	<10R 92Y	23R	85R	98R	100R	10R 90Y
Gas Sherardized	....	First R in 146 weeks. All R in 225 weeks				63R	92R	93R	97R	100Y	50Y	100Y	sl.R	22R	50R	47R	70R	<10R
Lead Plated		10R	<10R*	13R	16R*	0d	<10R	0d	Tr.R	<10R*	16R*	10R*	96Y 22R*	35Y 10R*	50Y 12R*	<10R*	15Y 16R*	90Y 15R

No. 14 by 2½-in Copper-Bearing Steel Flats

Electro Galvanized	0.29	99R	99R	100R	99R	First R in 44 weeks. All R in 147 weeks				0	0	0	0	66R	69R	86R	94R	0
Electro Galvanized	0.62	40R	64R	63R	37R	99R	99R	100R	....	0	0	0	0	0	0	0	0	<10Y
Hot Dip Galvanized	3.20	Tr.Y	sl.Y	10Y	Tr.Y	0	sl.Y	sl.Y	12Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.47	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	....	First R in 16 weeks. All R in 68 weeks				First R in 44 weeks. All R in 69 weeks				0	0	sl.Y	Tr.R	95R	99R	100R	....	53R
Electric Sherardized	....	First R in 16 weeks. All R in 225 weeks				First R in 44 weeks. All R in 174 weeks				sl.R 81Y	<10R 93Y	<10R 93Y	10R 90Y	10R	74R	86R	100R	10R 90Y
Gas Sherardized	....	83R	89R	90R	95R	76R	93R	96R	95R	100Y	100Y	100Y	100Y	45R*	61R	60R	73R	<10R 90Y
Lead Plated	....	<10R	<10R*	13R*	<10R*	0d	0d	0d	Tr.R	<10R*	12R*	15R*	22R*	<10R*	14R*	<10R	16R*	10R

¼ by 6-in. Bolts

Sherardized	0.68	0	0d	0	11R	0d	Tr.R	<10R	10R	100Y	0	100Y	Tr.R 98Y	First R in 96 weeks. All R in 226 weeks				50R
Sherardized	1.10	0	<10R	16R	55R	0d	28R	40R	87R	0	0	0	0	100Y	100Y	100Y	100Y	<10Y
Hot Dip Galvanized	1.61	60Y	55Y	100Y	38R 15Y	<10R 38Y	65R	80R	94R	0	0	0	Tr.R	0	0	0	0	0
Electro Galvanized	0.33	First R in 16 weeks. All R in 95 weeks				First R in 17 weeks. All R in 96 weeks				sl.R	<10R	15R	17R	First R in 44 weeks. All R in 226 weeks				85R
Cadmium Plated ... { Bolt Nut	0.29 0.10	All R in 16 weeks				First R in 44 weeks. All R in 69 weeks				First R in 16 weeks. All R in 199 weeks				First R in 121 weeks. All R in 226 weeks				First R in 52 weeks. All R in 206 weeks
Cadmium Plated ... { Bolt Nut	0.22 0.11	First R in 68 weeks. All R in 95 weeks				First R in 17 weeks. All R in 44 weeks				Tr.R	Tr.R Tr.Y	<10R	<10R	First R in 17 weeks. All R in 69 weeks				0

⅝ by 2½-in. Bolts

Sherardized	0.87	0	Tr.R	<10R	24R	Tr.Y	12R	30R	64R	0	0	100Y	100Y	100Y	100Y	100Y	100Y	27Y
Sherardized	0.70	0	Tr.R	Tr.R	<10R	0d	Tr.R	0d	Tr.R	100Y	100Y	100Y	100Y	<10R 47Y	24R	30R	63R	20R 80Y
Hot Dip Galvanized	1.40	10Y	45Y	60Y	15Y	60Y	50Y	60Y	Tr.R 61Y	0	0	0	0	0	0	0	0	0
Cadmium Plated	....	First R in 43 weeks. All R in 95 weeks				First R in 44 weeks. All R in 69 weeks				0	0	0	Tr.R	First R in 17 weeks. All R in 226 weeks				0
Cadmium Plated	1.49	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				First R in 16 weeks. All R in 120 weeks				First R in 17 weeks. All R in 44 weeks				First R in 52 weeks. All R in 263 weeks
Electro Galvanized	0.20	First R in 43 weeks. All R in 95 weeks				First R in 17 weeks. All R in 69 weeks				51R	67R	58R	64R	First R in 69 weeks. All R in 252 weeks				63R

½ by 2½-in. Bolts

Sherardized	0.84	0	Tr.R	Tr.R	<10R	0d	<10R	<10R	22R	50Y	0	sl.Y	100Y	100Y	50Y	100Y	100Y	<10Y
Sherardized	0.79	0	Tr.R	0	0	0d	0d	0d	Tr.R	100Y	100Y	100Y	100Y	<10R 46Y	23R	34R	60R	10R 90Y
Hot Dip Galvanized	1.48	10Y	45Y	60Y	20Y	60Y	50Y	60Y	13R 56Y	0	0	0	0	0	0	0	0	0
Electro Galvanized	0.21	First R in 68 weeks. All R in 95 weeks				First R in 17 weeks. All R in 69 weeks				<10R	21R	27R	46R	First R in 96 weeks. All R in 252 weeks				65R
Electro Galvanized	0.20	First R in 43 weeks. All R in 68 weeks				First R in 17 weeks. All R in 44 weeks				0	<10R	Tr.R	10R	First R in 69 weeks. All R in 174 weeks				<10R
Cadmium Plated	0.30	All R in 16 weeks				All R in 17 weeks				First R in 16 weeks. All R in 120 weeks				First R in 17 weeks. All R in 69 weeks				First R in 52 weeks. All R in 206 weeks

TABLE IV—REPORT ON INSPECTIONS OF METALLIC COATINGS, ETC. (*Continued*).

Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.				Exposure at Altoona, Pa.				Exposure at State College, Pa.				Exposure at Sandy Hook, N. J.				Exposure at KeyWest, Fla.
		4/24/33 225 weeks	10/23/33 251 weeks	4/23/34 277 weeks	10/29/34 304 weeks	4/25/33 226 weeks	10/24/33 252 weeks	4/24/34 278 weeks	10/30/34 305 weeks	4/25/33 225 weeks	10/24/33 251 weeks	4/24/34 277 weeks	10/30/34 304 weeks	4/26/33 226 weeks	10/25/33 252 weeks	4/25/34 278 weeks	10/31/34 305 weeks	2/7/34 263 weeks
$\frac{3}{8}$ by $1\frac{1}{2}$-in. Bolts																		
Sherardized	1.20	0	0d	0	0	0d	0d	0d	0	100Y	0	100Y	100Y	100Y	50Y	100Y	100Y	10R 90Y
Sherardized	0.89	0	11Y	<10Y	Tr.R	0d	0d	<10R	<10R	0	0	0d	50Y	Tr.R 50Y	13R	15R	38R	10Y
Hot Dip Galvanized	1.45	20Y	45Y	40Y	70Y	45Y	45Y	60Y	23R	0	0	0	0	0	0	0	0	0
Electro Galvanized	0.18	First R in 43 weeks. All R in 95 weeks				First R in 44 weeks. All R in 96 weeks				<10R	<10R	Tr.R	54R	First R in 44 weeks. All R in 200 weeks				98R
Cadmium Plated	0.14	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 44 weeks				25R	25R	25R	35R	First R in 76 weeks. All R in 226 weeks				<10Rth
Cadmium Plated	0.15	First R in 16 weeks. All R in 43 weeks				All R in 17 weeks				First R in 68 weeks. All R in 199 weeks				First R in 17 weeks. All R in 69 weeks				98R
1-in. Roofing Nails																		
Sherardized	0.90	First R in 146 weeks. All R in 225 weeks				First R in 200 weeks. All R in 252 weeks				100Y	<10R 50Y	100Y	25R 75Y	Tr.R 49Y	23R 35Y	23R	90R	100Y
Sherardized	0.86	First R in 146 weeks. All R in 225 weeks				First R in 200 weeks. All R in 252 weeks				100Y	<10R 50Y	100Y	25R 75Y	100Y	<10R 95Y	11R	15R 45Y	10R 90Y
Cadmium Plated	....	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 44 weeks				<10R 20Y	<10R 10Y	10R	45R	First R in 69 weeks. All R in 147 weeks				50R
Hot Dip Galvanized	1.34	50R	98R	100R	....	First R in 147 weeks. All R in 226 weeks				0	0	0	0	0	0	0	0	0
Hot Dip Galvanized	1.15	First R in 173 weeks. All R in 251 weeks				First R in 147 weeks. All R in 226 weeks				0	0	0	0	0	0	0	0	0
Electro Galvanized	....	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 121 weeks				70R 20Y	75R 13Y	90R	87R	92R	94R	90R	98R	80R
Amaloy	....	50R 50Y	33R 40Y	25R	45R 25Y	0d	50Y	0d	sl.R 45Y	....	95R	30R	87R	65R 25Y	75R 25Y	45R 30Y	45R* 25Y	First R in52 weeks. All R in 263 weeks
No. 14 by $2\frac{1}{2}$-in. Wood Screws																		
Sherardized	0.94	30R	85R	90R	100R	45R	72R	60R	100R	<10R 55Y	<10R 25Y	Tr.R	10R 47Y	20R 40Y	55R 20Y	60R	75R 10Y	20R
Sherardized	0.86	40R	85R	90R	90R	45R	72R	60R	100R	50Y	25Y	0d	<10R 47Y	Tr.R 99Y	10R	15R	20R	10R 10Y
Cadmium Plated	0.07	First R in 16 weeks. All R in 43 weeks				All R in 17 weeks				<10R	<10R	<10R	10R	13R	38R	45R	80R	<10R
Hot Dip Galvanized	1.26	Tr.R 50Y	<10R 80Y	Tr.R 90Y	33R 67Y	<10R 70Y	33R 50Y	15R	70R 10Y	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.04	First R in 16 weeks. All R in 43 weeks				All R in 17 weeks				First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 96 weeks				First R in 52 weeks. All R in 263 weeks
Hot Dip Galvanized	....	Tr.R 30Y	<10R 65Y	Tr.R 80Y	35R 65Y	sl.R 70Y	40R	25R	80R	0	0	0	0	Tr.Y	Tr.R	Tr.Y	0	0
Parkerized	....	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 69 weeks				All R in 16 weeks				First R in 17 weeks. All R in 44 weeks				All R in 52 weeks
		First R in 43 weeks. All R in 140 weeks				First R in 17 weeks. All R in 174 weeks				30R	37R	40R	55R					50R
Knockout Boxes																		
Electro Galvanized	0.21	22R	27R	43R	38R	60R	60R	66R	74R									
Electro Galvanized	0.16	85R	89R	96R	94R	92R	96R	98R	100R									
Hot Dip Galvanized	1.56	37Y	40Y							0	0	0	0	Tr.Y	Tr.Y	Tr.Y	Tr.Y	
Cadmium Plated										Tr.R	sl.Y	Tr.R	Tr.R					

KNOCKOUT BOXES																		
Electro Galvanized	0.21	22R	27R	43R	38R	60R	60R	66R	74R	0	0	0	0	Tr.Y	Tr.Y	Tr.Y	Tr.Y	0
Electro Galvanized	0.16	85R	89R	96R	94R	92R	96R	98R	100R	Tr.R	sl.Y	Tr.R	Tr.R	sl.R	11R	12R	30R	10Re
Hot Dip Galvanized	1.56	37Y	40Y	50Y	72Y	34Y	63Y	80Y	80Y	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.12	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				89R	94R	90R	99R	First R in 17 weeks. All R in 121 weeks				70R
Cadmium Plated	0.19	First R in 16 weeks. All R in 95 weeks				First R in 17 weeks. All R in 69 weeks				43R	44R	46R	52R	91R	91R	90R	94R	10Re
Electric Sherardized	0.28	First R in 95 weeks. All R in 146 weeks				First R in 96 weeks. All R in 252 weeks				100Y	Tr.R 99Y	Tr.R	11R	First R in 121 weeks. All R in 252 weeks				93R
Gas Sherardized	0.19	First R in 43 weeks. All R in 173 weeks				95R	98R	96R	98R	First R in 16 weeks. All R in 43 weeks				95R	83R	91R	99R	First R in 52 weeks. All R in 102 weeks
Electric Sherardized	0.28	50Y	<10R 30Y	90Y	<10R 15Y	20Y	75Y	70Y	90Y	59Y	75Y	100Y	63Y	100Y	100Y	50Y	100Y	10Y
Parkerized	....	First R in 16 weeks. All R in 173 weeks				45R	58R	60R*	45R*	83R*	85R	83R*	72R*	First R in 17 weeks. All R in 200 weeks				All R in 52 weeks
Amaloy	....	37R	33R*	40R*	31R*	0d	0d	0d	0d	73R*	85R	50R*	57R*	50R*	55R	45R*	70R*	72R
Hot Dip Aluminum	1.84	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
STEEL HINGES																		
Cadmium Plated	0.29	First R in 16 weeks. All R in 95 weeks				First R in 17 weeks. All R in 96 weeks				11R	24R	16R	29R	92R	98R	100R	....	22R
Cadmium Plated	0.32	First R in 43 weeks. All R in 95 weeks				First R in 44 weeks. All R in 96 weeks				0	0	0	Tr.R	91R	95R	100R	....	20R
Hot Dip Galvanized	1.54	Tr.R 67Y	<10R 70Y	10R 90Y	21R 31Y	70Y	<10R 91Y	13R 87Y	59R	0	0	0	0	0	0	0	0	0
Electric Sherardized	0.40	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				First R in 16 weeks. All R in 95 weeks				First R in 17 weeks. All R in 44 weeks				100Y
Gas Sherardized	0.68	57R	73R	70R	93R	29R	55R	60R	82R	Tr.R	Tr.R	Tr.R	Tr.R	Tr.R	28R	26R	44R	50Y
Parkerized	....	43R	93R*	80R	100R	0	0d	Tr.R	16R*	First R in 43 weeks. All R in 199 weeks				First R in 44 weeks. All R in 252 weeks				First R in 52 weeks. All R in 162 weeks
Electro Galvanized	0.19	First R in 16 weeks. All R in 95 weeks				First R in 17 weeks. All R in 96 weeks				41R	51R	53R	56R	95R	93R	96R	98R	First R in 52 weeks. All R in 162 weeks
BULLDOG CLAMPS																		
Electro Galvanized	3.41	11R	16R	23R	23R	10R	23R	13R	39R	0	0	0	0	0	<10R	0	<10Ra	0
Hot Dip Galvanized	1.88	<10R 50Y	Tr.R 40Y	60Y	<10R 15Y	75Y	<10R 26Y	80Y	10R 88Y	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.22	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				32R	70R	60R	74R*	First R in 17 weeks. All R in 44 weeks				First R in 52 weeks. All R in 162 weeks
Cadmium Plated	0.17	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 120 weeks				All R in 16 weeks				First R in 96 weeks. All R in 121 weeks				All R in 52 weeks
Gas Sherardized	0.46	50R	90R	100R	....	Tr.R	24R	10R	89R	50Y	Tr.R	60Y	50Y	93R*	100R	70R	97R	20R
Electric Sherardized	1.25	30R	40R	50R	21R	0d	10R	<10R	28R	25Y	Tr.R 25Y	0d	20Y	100Y	100Y	100Y	100Y	10Y
Electric Sherardized	0.58	30R	65R	75R	72R	28R	65R	73R	81R	25Y	0	0d	20Y	15R	32R	55R	73R	10Y
Hot Dip Aluminum	1.35	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	20Y
Parkerized	....	50R	63R*	70R	60R	0d	0d	0d	0d	62R*	90R*	60R*	85R*	First R in 17 weeks. All R in 174 weeks				All R in 52 weeks

TABLE IV.—REPORT ON INSPECTIONS OF METALLIC COATINGS, ETC. (*Continued*).

Abbreviations and Symbols Used: 0—no rust; 5, 10, 25, 100—approximate percentages; R—rusting of base metal; Y—yellow or orange alloy rust; *—rust spots widely distributed; d—black or dark surface film (soot or dirt); a—in angle; <—less than; e—edges; th—threads; Tr—trace; sl—slight; n—near; s—stain.

Coating	Weight, oz. per sq. ft. of surface	Exposure at Brunot Island, Pa.				Exposure at Altoona, Pa.				Exposure at State College, Pa.				Exposure at Sandy Hook, N. J.				Exposure at KeyWest, Fla.
		4/24/33 225 weeks	10/23/33 251 weeks	4/23/34 277 weeks	10/29/34 304 weeks	4/25/33 226 weeks	10/24/33 252 weeks	4/24/34 278 weeks	10/30/34 305 weeks	4/25/33 225 weeks	10/24/33 251 weeks	4/24/34 277 weeks	10/30/34 304 weeks	4/26/33 226 weeks	10/25/33 252 weeks	4/25/34 278 weeks	10/31/34 305 weeks	2/7/34 263 weeks
$\frac{1}{4}$ BY 3-IN. PLAIN STEEL FLATS																		
Electro Galvanized	0.76	98R	98R	....	99R	First R in 69 weeks. All R in 226 weeks				0	0	0	0	0	Tr.R	Tr.Y	<10R	0
Electro Galvanized	0.45	10R	40R	63R	81R	83R	83R	80R	95R	0	0	0	0	0	0	0	Tr.R	<10R
Hot Dip Galvanized	2.49	0	0	0	0	0d	Tr.Y	sl.Y	0d	0	0	0	0	Tr.R	Tr.R	Tr.R	Tr.R	0
Hot Dip Aluminum	0.90	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.23	First R in 43 weeks. All R in 95 weeks				First R in 17 weeks. All R in 69 weeks				Tr.R	<10R	12R	78R	98R	99R	99R	100R	10R
Electric Sherardized	....	First R in 146 weeks. All R in 146 weeks				First R in 17 weeks. All R in 147 weeks				100Y	100Y	100Y	100Y	sl.R	20R	22R	60R	10R
Gas Sherardized	0.12	First R in 16 weeks. All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				First R in 43 weeks. All R in 121 weeks				First R in 96 weeks. All R in 305 weeks				First R in 52 weeks. All R in 162 weeks
Lead Plated	....	22R	32R*	43R*	29R*	0d	Tr.Y	0d	<10R	45R*	65R*	40R	55R*	14R*	22R*	20R*	21R*	63R
$\frac{1}{4}$ BY 3-IN. COPPER-BEARING STEEL FLATS																		
Electro Galvanized	0.84	96R	97R	96R	98R	98R	99R	99R	100R	0	0	0	0	0	0	<10R <10Y	20R	0
Electro Galvanized	0.66	14R	26R	33R	43R	87R	88R	90R	96R	0	0	0	0	Tr.R	Tr.R	Tr.R	Tr.R	0
Hot Dip Galvanized	2.67	0	0	0	0	0	Tr.Y	sl.Y	Tr.Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.66	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	0.27	First R in 43 weeks. All R in 95 weeks				First R in 17 weeks. All R in 69 weeks				<10R	20R	26R	42R	First R in 44 weeks		All R in 252 weeks		<10R
Electric Sherardized	....	First R in 95 weeks. All R in 146 weeks				First R in 121 weeks. All R in 147 weeks				100Y	100Y	100Y	Tr.R 98Y	<10R	21R	17R	36R	10R
Gas Sherardized	0.18	All R in 43 weeks				First R in 17 weeks. All R in 44 weeks				First R in 68 weeks. All R in 146 weeks				First R in 44 weeks. All R in 96 weeks				First R in 52 weeks. All R in 162 weeks
Lead Plated	....	<10R	30R*	23R	34R*	0d	Tr.Y	0d	Tr.Y	40R*	42R*	30R	45R*	21R*	23R*	17R*	20R*	60R

No. 209 Window Frame Sections																		
Electro Galvanized	0.67	98R	99R	100R	....	95R	98R	98R	97R	0	0	Tr.R	<10R	Tr.Ra	<10R	<10R	14Ra	<10Ra
Electro Galvanized	0.24	83R	94R	98R	98R	89R	90R	83R	98R	0	0	0	Tr.R	37R	41R	40R	51R	0
Hot Dip Galvanized	3.10	0	0	0	Tr.Y	0	Tr.Y	0	<10Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.61	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.24	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 96 weeks				32R	37R	33R	46R	84R	89R	95R	78R	55R
Electric Sherardized	0.52	First R in 146 weeks. All R in 199 weeks				First R in 147 weeks. All R in 252 weeks				100Y	100Y	100Y	100Y	<10R	42R	40R	70R	10R 90Y
Amaloy	....	32R	23R*	26R	50R*	0d	Tr.Y	0d	Tr.R	64R*	66R	70R*	75R*	31R*	34R	28R	41R*	50R
No. 792 Window Frame Sections																		
Electro Galvanized	0.54	98R	99R	100R	....	84R	90R	90R	98R	10Ra	14Ra	<10Ra	20Ra	57Ra	45Ra	45Ra	55Ra	0
Electro Galvanized	0.35	First R in 16 weeks. All R in 251 weeks				First R in 17 weeks. All R in 174 weeks				13Ra	18Ra	<10Ra	26Ra	71Ra	70R	76R	86R	43R
Hot Dip Galvanized	2.60	Tr.Y	sl.Y	sl.Y	Tr.R sl.Y	Tr.Y	sl.Y	sl.Y	<10R 17Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	1.30	0d	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	0
Cadmium Plated	0.22	First R in 16 weeks. All R in 120 weeks				First R in 17 weeks. All R in 96 weeks				Tr.R	<10R	<10R	<10Ra	74R	76R	90R	94R	10R
Cadmium Plated	0.17	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 69 weeks				30Ra	40R	30Ra	55R	92R	99R	100R	....	50R
Electric Sherardized	0.57	33R	39R	60R	77R	24R	57R	60R	75R	100Y	90Y	100Y	85R	40R	53R	58R	59R	70Y
Gas Sherardized	0.58	85R	95R	100R	....	74R	80R	90R	88R	25R 75Y	12R 46Y	10R	34R 66Y	Tr.R 99Y	Tr.R 98Y	100Y	100Y	30R 70Y
Parkerized	....	First R in 43 weeks. All R in 95 weeks				First R in 44 weeks. All R in 252 weeks				First R in 43 weeks. All R in 120 weeks				First R in 17 weeks. All R in 69 weeks				All R in 52 weeks
No. 161 Window Frame Sections																		
Electro Galvanized	0.89	88R	95R	98R	99R	89R	90R	90R	98R	15Ra	23R	13R	23R	60R	73R	78R	80R	0
Electro Galvanized	0.81	88R	97R	99R	100R	88R	92R	92R	98R	<10Ra	10R	<10R	15R	27R	30Ra	40Ra	43Ra	22R
Hot Dip Galvanized	2.97	0	Tr.Y	0	Tr.Y	Tr.Y	Tr.Y	sl.Y	10Y	0	0	0	0	0	0	0	0	0
Hot Dip Aluminum	0.66	0	0d	0d	0d	0d	0d	0d	0d	0	0	0	0	0	0	0	0	<10Y
Cadmium Plated	0.22	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 69 weeks				42R	54R	46R	61R	80R	88R	92R	93R	10Ra
Cadmium Plated	0.15	First R in 16 weeks. All R in 68 weeks				First R in 17 weeks. All R in 69 weeks				73R	75R	70R	73R	First R in 17 weeks. All R in 252 weeks				87R
Electric Sherardized	0.32	<10R	36R	30R	41R	22Ra	62R	50R	87R	85Y	86Y	100Y	100Y	Tr.R 87Y	sl.R 90Y	Tr.R 100Y	Tr.R 100Y	75Y
Gas Sherardized	0.42	35R	84R	80R	81R	39Ra	66R	50R	78R	100Y	100Y	Tr.R 100Y	Tr.R 99Y	<10R	19R	20R	41R	100Y
Parkerized	....	First R in 68 weeks. All R in 95 weeks				74R	91R	90R	100R	First R in 43 weeks. All R in 95 weeks				First R in 17 weeks. All R in 96 weeks				All R in 52 weeks

REPORT OF COMMITTEE A-6

ON

MAGNETIC PROPERTIES

Committee A-6 on Magnetic Properties held two meetings during the year at Society Headquarters in Philadelphia, Pa., on December 7, 1934, and on April 12, 1935.

Two new subcommittees have been appointed, namely, Subcommittee IV on Tests of Electrical Sheet Having Pronounced Directional Properties consisting of B. M. Smith, chairman, W. J. Shackelton, and R. L. Sanford; Subcommittee V on Core Loss Tests of Electrical Sheet at High Inductions, B. M. Smith, chairman, C. W. Rust, and P. H. Dike.

Mr. Andrew Pinkerton, after many years of service on the committee, has resigned and the appointment of Mr. O. E. Romig of the American Sheet and Tin Plate Co. was approved. Mr. Kenneth Metcalfe of the Crucible Steel Co. was appointed to succeed Mr. F. H. Allison, Jr., who has resigned due to a change of occupation. Mr. J. P. Barton of the Empire Sheet and Tin Plate Co. has been reappointed a member of the committee.

RECOMMENDATIONS AFFECTING STANDARDS

Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 33).[1]—Several proposed additions and a few changes in these methods have been prepared. The committee recommends that these modifications which are appended hereto[2] be published as tentative revisions of the Standard Methods A 34. The changes include a modification of Section 2 in order to make provision for the testing of sheet material having preferred magnetic properties with reference to the direction of rolling. Provision is also being made for the use of two more permeameters for high magnetization testing of normal induction and hysteresis. These include the simplex super-H adapter and the saturation permeameter both suitable for tests at magnetizing forces between 100 and 2500 oersteds. A modification in Section 5 of the methods is also proposed in order to take care of the testing of some of the new very high coercive force permanent magnet steels.

Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 34).[3]—The committee has prepared several new definitions and revisions in the definitions of a number of the terms included in the Standard Definitions A 127. These include new definitions for "intrinsic induction curve," "magnetician," and "normal induction curve"; and revised definitions for "oersted," "coercive force," "coercivity," "ferromagnetic material," "magnetic induction," "magnetizing force," "normal induction," "permeability," and "retentivity." The committee believes that these should be issued as tentative. These new and revised terms have accordingly been incorporated in the proposed Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing, appended hereto,[1] which are recommended for publication as tentative to supersede when adopted as standard the present Standard Definitions A 127 – 34.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 396.

[2] See p. 1389.—ED.

[3] 1934 Supplement to Book of A.S.T.M. Standards, p. 69.

The above recommendations have been submitted to letter ballot of the committee, which consists of 17 members; 15 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
PROPOSED REVISION OF STANDARDS			
Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 33)	15	0	0
Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 34)	15	0	0

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Nomenclature and Definitions (W. J. Shackelton, chairman).—As a result of a number of suggestions received both from within and outside of the committee, a number of changes and additions to the Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 34) adopted last year, have been recommended for publication as tentative as appended hereto.[1] These changes have been, in general, directed toward simplification and clarification. The definitions given at the beginning of the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 33) are also to be changed to agree with those in the complete list of definitions in A 127.

Subcommittee II on Alternating Current Tests at Low Inductions (R. L. Sanford, chairman).—Shortly after the development of the low-induction tests, it was noted that after demagnetization the magnetic properties at low inductions of various kinds of commercial magnetic materials changed very considerably, these changes being quite rapid at first and gradually decreasing in rate. Many hours were required for stabilization. A second demagnetizing treatment would result in a repetition of the phenomena. Pending a better understanding of these effects, it is proposed simply to call attention to them; with the understanding that when sufficient information becomes available definite test procedure will be specified to cover this source of uncertainty.

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[1] See p. 726.—ED.

Subcommittee III on Tests at High Magnetizing Forces (L. E. Howard, chairman).—With the advent of several new permanent magnet materials having coercive forces of several hundred oersteds the present requirements for testing became inadequate. The subcommittee is making extensive studies of various test methods by means of round-robin tests on carefully prepared bars of these materials, with the object of developing new test devices and determining the limitations of existing ones. In order to provide immediate means of test two permeameters suitable for operation up to 2500 oersteds or higher are offered as mentioned earlier in this report, namely, the saturation permeameter and Fahy's new simplex super-H adapter to be used with the simplex permeameter.

Subcommittee IV on Tests of Electrical Sheet Having Pronounced Directional Properties (B. M. Smith, chairman).—Electrical sheet material having very much better magnetic properties in the direction of sheet rolling and very much poorer properties at right angles than ordinary commercial sheet, is becoming available commercially. For these materials, obviously, the 50-50 Epstein sample is unsuitable since this material must be used with the flux approximately parallel to the direction of sheet rolling. Accordingly an addition to the methods of testing has been recommended, as mentioned earlier in this report, permitting the use of the parallel sample only for this class of material. At a later time the methods may be made more definite with reference not only to direction of grain but also to test inductions.

Subcommittee V on Core Loss Tests of Electrical Sheet at High Inductions (B. M. Smith, chairman).—It has been shown by the chairman of this subcommittee that the standard test for core losses at 14 kilogausses does not always class materials correctly if they are to be used at 15 kilogausses or higher. This may be due to scale or other causes. It is proposed, therefore, that a higher induction test be adopted. Opposition to this suggestion is based on the difficulty of making accurate tests at the higher inductions. It is the purpose of this subcommittee to make round-robin tests of Epstein samples in various commercial laboratories to determine the amount of variation to be expected and on the basis of the results to offer recommendations with reference to increasing the testing inductions.

This report has been submitted to letter ballot of the committee which consists of 17 members; 15 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

THOMAS SPOONER,
Chairman.

R. L. SANFORD,
Secretary.

REPORT OF COMMITTEE A-10

ON

IRON-CHROMIUM, IRON-CHROMIUM-NICKEL AND RELATED ALLOYS

Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys has held one meeting during the year, in Philadelphia, Pa., on March 7, 1935, during the Spring Group Meetings of A.S.T.M. Committees. Several changes in committee personnel have occurred resulting in a present membership of 63, of whom 26 are classed as producer, 28 as consumer, and 9 as general interest members.

Mr. W. R. Huey resigned the chairmanship of Subcommittee IV on Methods of Corrosion Testing and Mr. E. S. Taylerson has been selected to succeed him.

The committee records with deep regret the death of Dr. John A. Mathews, who was always keenly interested in its work and took a prominent part in its discussions.

The committee has under consideration the organization of a new subcommittee to be designated Subcommittee XI on Specifications for Tubular Products.

At the meeting of the committee held in Washington, D. C., on March 9, 1934, it was decided to hold a round-table discussion on the fabrication and performance of alloys falling within the scope of Committee A-10. Commercial developments in certain classes of service made the success of this discussion very problematical so that this objective could not be attained. It was decided at the meeting in Philadelphia, however, that such a program would be possible in 1936 and arrangements for it are to be made.

Recommendations Affecting Standards

Proposed Tentative Standards.—The committee recommends for publication as tentative the following four specifications, as appended hereto:

Proposed Tentative Specifications for:

- Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate)[1]
- 12 per cent Chromium Steel Castings[1]
- 19 per cent Chromium Steel Castings[1]
- 28 per cent Chromium Steel Castings[1]

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[1] See pp. 667, 623, 627, and 631.—Ed.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 63 members; 37 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
PROPOSED TENTATIVE STANDARDS			
Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate)	31	1	4
Specifications for 12 per cent Chromium Steel Castings	31	2	4
Specifications for 19 per cent Chromium Steel Castings	31	2	4
Specifications for 28 per cent Chromium Steel Castings	32	2	3

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Classification of Data (T. H. Nelson, chairman).—This subcommittee, which is assembling accepted data on chemical, physical, mechanical and fabricating properties of chromium and chromium-nickel steels, has made progress both in respect to the accumulation of the data and the form in which it may be most concisely and economically presented. The data are not yet sufficiently complete for presentation to Committee A-10.

Subcommittee III on Methods of Chemical Analysis (F. B. Foley, chairman).—At the June, 1933, meeting of Committee A-10, Mr. Foley discussed the advisability of consolidating methods of chemical analysis of metals in one committee of the Society, which would replace the present subcommittees on chemical analysis that are now organized under the individual standing committees. Similar discussions have taken place in other committees and it is planned that an organization meeting of the new standing committee on Chemical Analysis of Metals be held during the current annual meeting of the Society. As soon as the new committee begins to function Subcommittee III will be disbanded.

Subcommittee IV on Methods of Corrosion Testing.—The program of tests outlined in the 1934 report[1] of Committee A-10 has been developed further, particularly in the direction of undertaking atmospheric exposure tests in conjunction with the laboratory tests on the several materials available to this subcommittee. No actual work on this new program has been undertaken.

Subcommittee V on Mechanical Testing (C. A. Scharschu, chairman).—A complete program for the study of the elastic properties of the 18 per cent chromium, 8 per cent nickel types of steel in various states of heat treatment and cold working has been outlined and the task of preparing the material has begun.

Subcommittee VI on Metallography (C. E. MacQuigg, chairman).—This subcommittee is at present engaged in studying the electrolytic method of etching as applied particularly to the nickel-chromium steels for the detection of a second phase (generally assumed to be a chromium-rich carbide). The subcommittee has not thus far had sufficient agreement in its work to propose a recommended procedure.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 190 (1934).

Subcommittee VII on Welding (F. B. Olcott, chairman).—This subcommittee held a meeting in March and considered a draft of proposed specifications for welded austenitic steel which had been somewhat revised during the year owing to certain developments in this field. The specifications will be further considered by the members of the subcommittee with the view of arriving at more definite conclusions at the time of the next meeting, which will be held in June. There are so many ramifications to the development of the welding of this type of alloy that the subcommittee can only report progress at this time.

Subcommittee VIII on Specifications for Wrought Products (F. B. Foley, chairman).—The subcommittee has been working in very close association with the Technical Group of the Stainless Steel Producers and expects shortly to be in a position to prepare specifications for some of the types of products falling within its jurisdiction.

Subcommittee IX on Specifications for Flat Products (C. C. Snyder, chairman).—This subcommittee has been engaged during the past year in devising specifications to cover the various corrosion-resisting ferrous alloys in the form of flat products. Originally it was the intention of the subcommittee to combine all the various types into a single specification. Discussion at the March meeting, however, disclosed the opinion that it would perhaps be better to divide the specifications into two parts, one covering the chromium-nickel steels, and the other, the straight chromium steels. There will be a third specification for high tensile strength materials which at the present time would include only the chromium-nickel steels.[1] The first of these specifications, namely, the proposed Tentative Specifications for Corrosion-Resisting Chromium-Nickel Steels (Sheet, Strip and Plate) has been completed and is being presented for publication as tentative, as appended hereto.[2]

Subcommittee X on Specifications for Castings (W. J. Jeffries, chairman).—This subcommittee has prepared three specifications dealing with castings of the plain chromium steels, namely, proposed Tentative Specifications for 12 per cent Chromium Steel Castings, for 19 per cent Chromium Steel Castings, and for 28 per cent Chromium Steel Castings, which are being presented for publication as tentative, as appended hereto.[3] Additional specifications for the various chromium-nickel cast steels are in process of formulation and it is hoped that at least two of them will be prepared in time for presentation to the Society through Committee E-10 on Standards subsequent to the annual meeting.[1]

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[1] See Editorial Note, p. 110.—Ed.
[2] See p. 667.—Ed.
[3] See pp. 623, 627 and 631.—Ed.

This report has been submitted to letter ballot of the committee, which consists of 63 members; 37 members returned their ballots, of whom 35 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

JEROME STRAUSS,
Chairman.

H. D. NEWELL,
Secretary.

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[1] See Editorial Note, below.—ED.

EDITORIAL NOTE

Subsequent to the annual meeting Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys presented to the Society on August 22, 1935, through Committee E-10 on Standards the following additional proposed tentative specifications:

Proposed Tentative Specifications for:

- 24 per cent Chromium, 12 per cent Nickel Alloy Steel Castings.
- 25 per cent Chromium, 20 per cent Nickel Alloy Steel Castings.
- 28 per cent Chromium, 9 per cent Nickel Alloy Steel Castings.
- 20 per cent Nickel, 9 per cent Chromium Alloy Steel Castings.
- 35 per cent Nickel, 15 per cent Chromium Alloy Steel Castings.
- Corrosion-Resisting Chromium Steels (Sheet, Strip and Plate).
- High-Strength Corrosion-Resisting Chromium-Nickel Steels (Sheet and Strip).

The above specifications were accepted by Committee E-10 and appear respectively on pp. 635 to 681, inclusive.

REPORT OF THE RESEARCH COMMITTEE ON FATIGUE OF METALS

The Research Committee on Fatigue of Metals has held one meeting this year during the Spring Group Meeting of A.S.T.M. Committees in March at Philadelphia. The activities of the committee during the year are summarized in this report:

Cooperation with Committee E-4 on Metallography.—The committee has been cooperating with Subcommittee VI on X-ray Methods of the A.S.T.M. Committee E-4 on Metallography. The following progress report has been submitted by R. F. Mehl representing Committee E-4, and R. L. Templin representing the Research Committee:

THE X-RAY AS A MEANS OF DETECTING IMPENDING FATIGUE FAILURE

A study of the possibilities of detecting damage to metallic materials by repeated stresses and thus predicting when a material is about to fail in fatigue is in progress at the Carnegie Institute of Technology. In this work specimens of an aluminum alloy and of structural silicon steel have been examined.

The aluminum alloy shows no detectable widening of the Debye Lines as a result of repeated stressing. If subsequent measurements of the photograms should prove widening of these lines to occur, the widening will be so small as to offer no hope for a practical method of detecting impending fatigue failure.

In the case of the structural silicon stressing repeatedly at, or slightly below, the endurance limit for 81 million cycles appears to widen the Debye Lines, but the effect is small and microphotometer measurements are required to prove it definitely. This widening is, however, probably only an indication of the beneficial cold-working which occurs when a material is stressed below, or at least not above, its endurance limit.

Line widening has thus proved quite insensitive as a measure of the progress of fatigue, and it has been shown that the peripheral widening of defraction spots on a stationary film (which is equivalent to asterism on a photogram taken with white radiation) is quite a sensitive method and bears considerable promise as an indication of the fatigue process in ferrous alloys. On aluminum alloys, however, there is only a very small effect. In steels the sensitivity is greater the lower the carbon content. This work has not yet progressed far enough to draw any conclusions concerning the meaning of the results.

Cooperation with "Metals and Alloys."—The Research Committee has continued its cooperation with *Metals and Alloys* in preparing abstracts of articles dealing with fatigue of metals and in planning and preparing critical abstracts on this subject.

Notes on the Technique of Fatigue Tests.—As this committee is a research committee, and is not balanced at all between producers and consumers, it has not formulated standards. However, it is within its province to publish recommended practices or notes on methods of testing. Such a set of notes has been prepared in connection with the commonest fatigue test in use, namely, the test in which a rotating-beam testing machine is used. These notes are appended to this report.

Problems Discussed by the Committee.—The problem of the fatigue strength of steel-core copper-coated wires (copperweld) was presented at the March meeting of the committee, and suggestions were made for the investigation of the problem which is of interest in connection with the mechanical strength of electric transmission lines.

Experiments on determining the damage done to metal by occasional heavy overstress were reported, following the "damage line" method of H. J. French.[1] This method of investigation gives promise of usefulness in the very important problem of determining how sensitive a metal is to damage under occasional overload. This is, perhaps, fully as important as the problem of the strength of a metal under ordinary working stresses.

New types of testing machines for fatigue testing were discussed, especially machines for testing wire. The machines of Shelton and Swanger,[2] of De Forest,[3] and the British machine of Professor Haigh[4] of Greenwich were mentioned and also a scheme for fatigue testing of wire mentioned by R. R. Moore.

Respectfully submitted on behalf of the committee,

H. F. MOORE,
Chairman.

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[1] *Transactions*, Am. Soc. for Metals, Vol. XXI, No. 10, p. 899, October, 1933.

[2] National Bureau of Standards *Journal of Research*, Vol. 14, January, 1935.

[3] A. V. de Forest and L. W. Hopkins, "The Testing of Rope Wire and Wire Rope," *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part II, p. 398 (1932).

[4] *Engineering* (London), Vol. CXXXVIII, No. 3578, p. 139 (August 10, 1934).

APPENDIX

NOTES ON FATIGUE TESTS ON ROTATING-BEAM TESTING MACHINES

Purpose of Notes.—At the present time the commonest test for fatigue strength of metals is the rotating-beam test, in which a transverse load on a rotating specimen sets up a cycle of reversed flexural stress for every revolution of the specimen. These notes cover tests made on rotating-beam testing machines either of the centrally loaded or the cantilever type.

Testing Machines and Specimens

The fatigue testing machine shown in Fig. 1 uses a specimen which acts as a simple beam (no restraint at end supports), loaded at two points symmetrically spaced between the end supports in the manner indicated, and it is rotated while under load. From an examination of the bending moment diagram of such a beam it is evident that the bending moment is uniform between the load points. If the cross-section of the specimen were uniform between these load points then the stress in the specimen, neglecting the concentrations of stress at the load points, would be uniform over the middle portion of the specimen. Due to the concentration of stress set up by the clamping collets at the points where the load hangers are attached, however, the specimen will break there prematurely unless precautions are taken to prevent this. This difficulty is overcome by gradually reducing the cross-section of the test specimen between the load points as is indicated in Fig. 1 and again in the detail of the test specimen as shown in Fig. 4. In making this reduction it is very important that the transition from the large to the small cross-section be very gradual, as small radii or fillets will influence the location and time of the failure due to concentrated stresses. Experience has shown that specimens made to the form of Fig. 4, which indicates a large radius of curvature in the reduced section, will be free from appreciable stress concentration. The actual stress at the minimum section of a specimen, as shown, checks very well with the value calculated by means of the common flexural formula. It is suggested that the radius (Figs. 4, 5 and 6) be not less than six times the minimum diameter of specimen.

It should be noted particularly that in this type of test the stress is not uniformly distributed over the cross-section of the specimen, but varies from a maximum at the outer fibers to zero at the neutral axis. The fibers at the top of the specimen are in compression and the fibers at the bottom are in tension. When the specimen is rotated one-half revolution this condition is reversed; the fibers that were in tension now are in compression and *vice versa*. Thus, with each revolution the specimen is subject to a complete cycle of reversed stress from tension to compression.

In the machine shown in Fig. 2, the portions of the specimen between the load points and the end supports are replaced by two spindles. The test specimen is of sufficient length to extend between the load points. This scheme has been used in ball-bearing type machines and also in a plain bearing type machine as shown in Fig. 2. It is evident that the conditions of stress developed in the specimen are the same as described for the long specimen type, namely, a complete cyclical reversal of flexural stress.

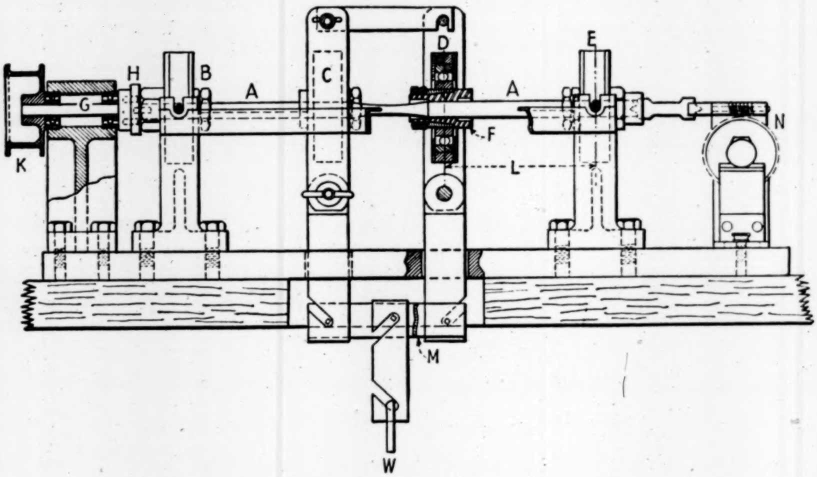

FIG. 1.—Long-Specimen Rotating-Beam Fatigue Machine. (Sondericker or Farmer Type.

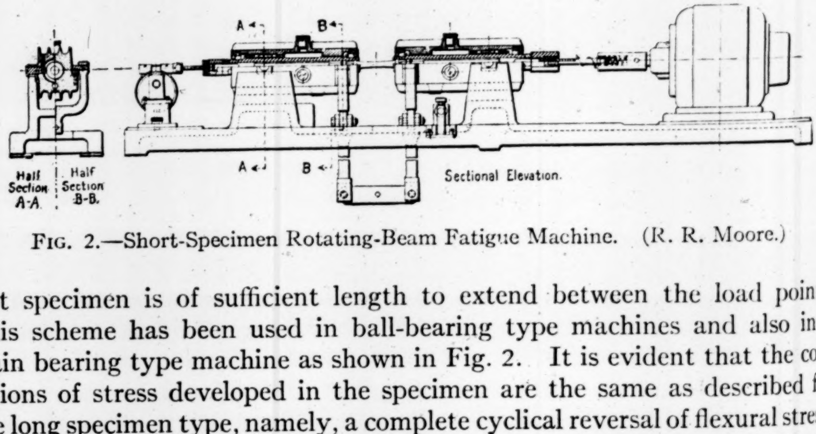

FIG. 2.—Short-Specimen Rotating-Beam Fatigue Machine. (R. R. Moore.)

The test specimen for this short-specimen machine is shown in Fig. 5. and it will be noted that the minimum radius of curvature at the reduced section should be not less than that suggested for the long specimen.

The short-specimen type of machine possesses several advantages over the long-specimen type. In the short-specimen machine the moment arms (distance from end supports to load points) are accurately and permanently fixed when the machine is built, and remain constant regardless of shape or size of specimen. In the long-specimen machine the moment arm is reset for every specimen placed in the machine, with consequent possibility of error in the assumed length of arm. When it is desired to cut fatigue specimens from machine or structural parts it is frequently impossible to obtain a long specimen. When testing soft metals, such as aluminum or magnesium, it is difficult to machine a long specimen without bending it, and difficult to place it in the testing machine without bending or otherwise distorting it.

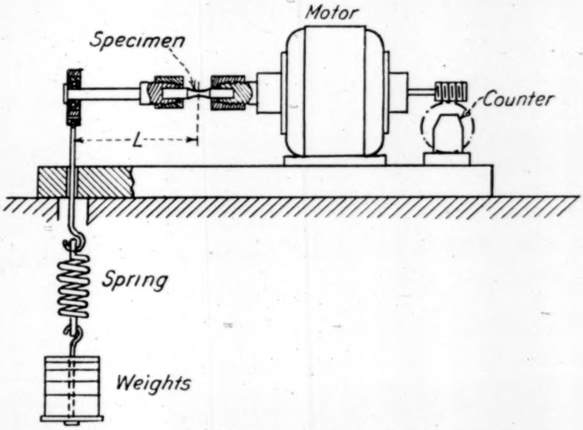

FIG. 3.—Cantilever Type Fatigue Testing Machine.

The fatigue testing machine shown in Fig. 3 is of the cantilever type. In this machine the bending moment on any given cross-section of the specimen varies directly as the distance of the cross-section from the point of support of the weights hung on the specimen. The bending moment is a maximum at the jaws of the chuck which holds the specimen. An advantage of the cantilever type of machine is that it has but three bearings, and that a simple specimen may be used.

Figure 6 shows a type of specimen suitable for use in a cantilever testing machine. Although the bending moment varies along the specimen from weights to chuck, it is possible by tapering the specimen, or by turning down the reduced section on a large radius (see Fig. 6), to keep the extreme fiber stress within a range of 1 per cent for an appreciable length along the specimen. In Fig. 6 the length of this region of slight variation in fiber stress is shown.

Comparative fatigue tests on centrally-loaded machines and on cantilever machines indicate that for the common structural metals the endurance limit determined does not depend to any appreciable extent on the type of testing machine.[1]

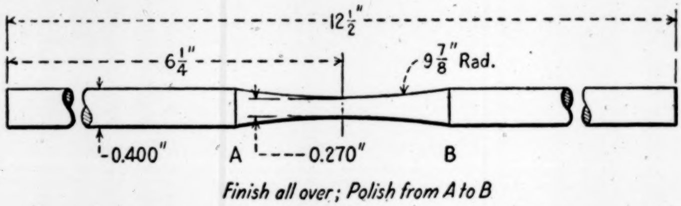
12 1/2"
6 1/4"
9 7/8" Rad.
0.400"
A
0.270"
B
Finish all over; Polish from A to B

FIG. 4.—Test Specimen for Long-Specimen Rotating-Beam Machine. (H. F. Moore.)

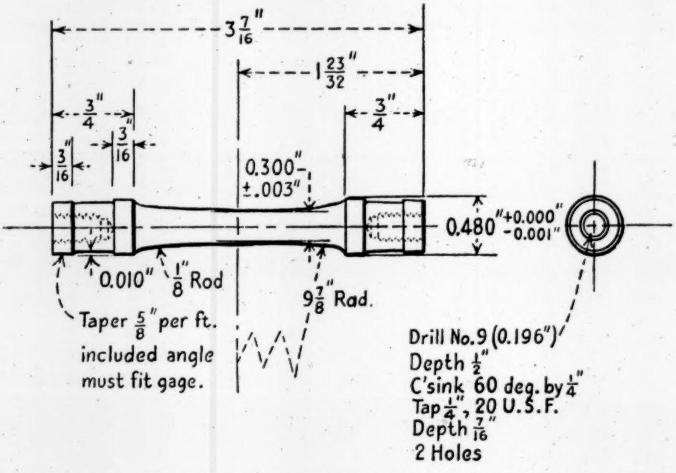
3 7/16"
1 23/32"
3/4"
3/16"
3/16"
3/4"
0.300" ±.003"
0.480" +0.000" -0.001"
0.010"
1/8" Rod
9 7/8" Rad.
Taper 5/8" per ft. included angle must fit gage.
Drill No. 9 (0.196")
Depth 1/2"
C'sink 60 deg. by 1/4"
Tap 1/4", 20 U.S.F.
Depth 7/16"
2 Holes

FIG. 5.—Test Specimen for Short-Specimen Rotating-Beam Machine. (R. R. Moore.)

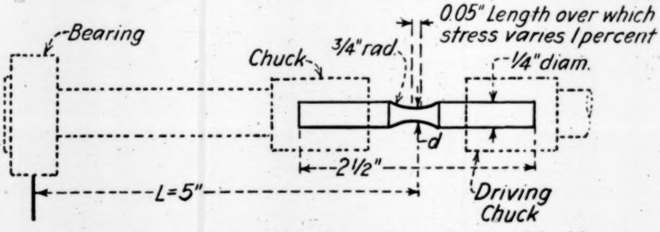
Bearing
Chuck
3/4" rad.
0.05" Length over which stress varies 1 percent
1/4" diam.
d
2 1/2"
L=5"
Driving Chuck

FIG. 6.—Specimen for Cantilever Type Testing Machine.

Speed and Vibration of Testing Machine.—Evidently the time required to determine endurance limit may be shortened by using high-speed testing machines. However, this raises the question of the effect of speed of testing on endurance limit. In general, test data available today indicates that speed effect for small specimens is not appreciable between 200 cycles of stress per minute and 5000 cycles of stress per minute, and is not very great for 10,000 cycles per minute.[1]

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[1] G. N. Krouse, "A High-Speed Fatigue Testing Machine and Some Tests of Speed Effect on Endurance Limit," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 156 (1934).

It is important that in a rotating-beam testing machine the specimen should run smoothly in order to avoid inertia stresses in the specimen. No general quantitative rules for allowable vibration are suggested, but it should be kept as low as possible. In Figs. 1, 2, and 3 the weights hung on the specimen are suspended by coiled springs. If these weights vibrate as they hang free, their vibration can usually be stopped by using the dead weights to *apply* the load, and by *maintaining* the load by means of adjusting nuts on a threaded rod as shown in Fig. 7.

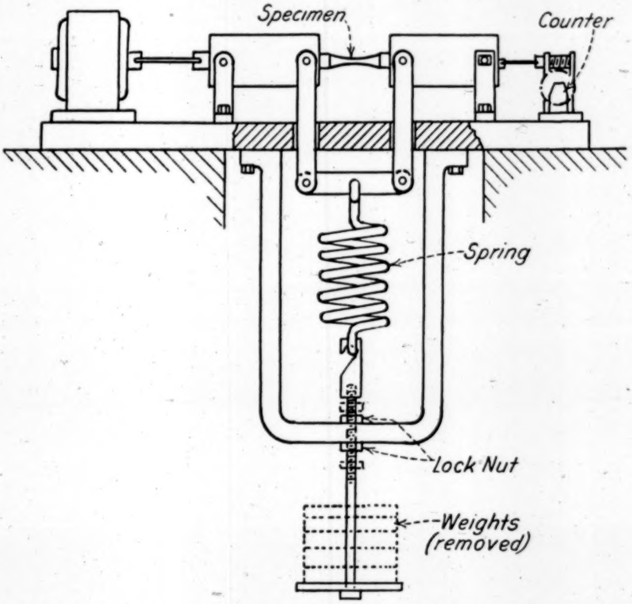

FIG. 7.—Loading Rig to Minimize Vibration of Specimen. (Templin)

Machining and Finish of Specimens.—The presence of scratches or tool marks on fatigue specimens produces stress concentration and affects the determination of endurance limit appreciably. Circumferential scratches or tool marks are more injurious than are longitudinal ones. It is important in the preliminary machining of specimens, especially specimens of soft metals, that the machining should be done with a sharp tool, using a relatively light cut and slow speed, or with a grinding wheel which is kept running cool. Contoured tools used to finish specimens to shape are especially likely to damage the surface.

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[1] *Bulletin 136*, p. 58, Engineering Experiment Station, University of Illinois, Urbana, Ill.
G. N. Krouse, "A High-Speed Fatigue Testing Machine and Some Tests of Speed Effect on Endurance Limit," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 159 (1934).
See also list of references in *Bulletin 124*, p. 27, Engineering Experiment Station, University of Illinois, Urbana, Ill.

The final finish of the reduced-diameter part of the specimen should be such that no circumferential scratches can be seen by the unaided eye. For producing the final finish No. 00 emery cloth is satisfactory for some metals. No. 000 Manning paper is preferable for others, and for a very fine finish No. 65 levigated alumina may be used. Polishing is best done by moving the abrasive in a direction parallel to the axis of the specimen rather than at right angles to that axis, in order that circumferential scratches may be minimized. The specimen may be slowly rotated during the polishing.

TEST PROCEDURE

The minimum diameter of the specimen may be measured with a round-nose micrometer, a traveling microscope with micrometer eyepiece, or other instrument having a sensitivity of 0.5 per cent of the diameter measured.[1]

It is desirable to have at least six specimens for the determination of endurance limit of a metal. The endurance limit may be roughly estimated from tensile strength or Brinell hardness number, and the first specimen put into the machine with a load on it which will set up a stress well above the estimated endurance limit. The load to produce a given stress is calculated from the formulas:

$$W = \frac{\pi d^3 S}{16\,L} \text{..........................for specimen as per Fig. 1 or Fig. 2}$$

$$\text{or}\quad W = \frac{\pi d^3 S}{32\,L} \text{..........................for specimen as per Fig. 3}$$

where, W = the load on the specimen in pounds (including weight of parts of machine),

S = the nominal extreme fiber stress in pounds per square inch,

L = the moment arm in inches (distance from end support to load point), and

d = the minimum diameter of specimen, in inches.

After the first specimen has fractured the other specimens are then tested at successively lower stresses until a specimen "runs out" to some arbitrarily chosen number of cycles of stress without fracture. This number of cycles of stress may usually be taken as 10,000,000 cycles for ferrous metals, while for non-ferrous metals a larger number is usually necessary, running as high as 500,000,000 cycles for certain non-ferrous alloys. In determining an endurance limit at least one specimen should "run out" without fracture to the arbitrarily chosen number of cycles.

It has been found that applying repeated cycles of stress *below the endurance limit* of a metal increases its resistance to fracture by repeated stress. Hence, the practice of running a specimen for a large number of times at a low stress, then increasing the load a little and again subjecting it to a large number of cycles of stress, and keeping up this procedure until the specimens finally breaks, *does not locate the endurance limit at all accurately.* The understressing strengthens the metal, and the fracture occurs at a stress *higher* than the endurance limit of the virgin metal.

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[1] The use of a round-nose micrometer may cause appreciable abrasion of the surface of a specimen of s metal. A sensitivity of micrometer of 0.2 per cent of the diameter of specimen is desirable, when feasible.

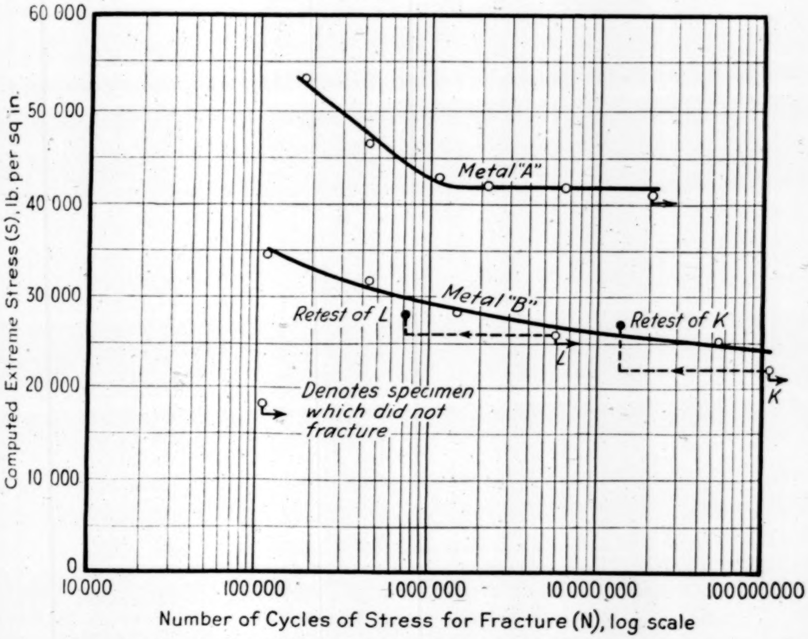

FIG. 8.—Typical *S-N* (Stress-Cycle) Diagrams for Fatigue Tests.

Recording and Plotting Data of Rotating-Beam Fatigue Tests.—It is suggested that the test data recorded for a rotating-beam fatigue test include the following:

1. As complete a description of material as possible.
2. Type of testing machine used.
3. Number of cycles of stress per minute.
4. Type and nominal dimensions of specimen.
5. For each specimen tested:
    - (*a*) Measured diameter of specimen.
    - (*b*) Calculated extreme fiber stress.
    - (*c*) Number of cycles withstood.
    - (*d*) Location and distinguishing characteristics of fracture.
6. Endurance limit.
7. Number of cycles of stress on which endurance limit is based.

It is suggested that the test data be plotted to semi-logarithmic coordinates as shown in Fig. 8. Such diagrams as are shown in Fig. 8 are known as "stress-cycle" or "*S-N*" diagrams.

The Determination of Endurance Limit from an S-N Diagram.—In the *S-N* diagram, Metal "A" in Fig. 8, the determination of endurance limit is simple. The diagram has become horizontal, and the ordinate of the horizontal portion gives the endurance limit directly, 42,000 lb. per sq. in. In the *S-N* diagram, Metal "B" in Fig. 8, the diagram has *not* become horizontal, and a value of endurance limit may be reported as the limit for a definite number of cycles. In the case of Metal "B" it would be reported as 24,500 lb. per sq. in. for 100,000,000 cycles of stress.

It should be noted that the point for a test in which the specimen did not fracture is not necessarily a point *on* the *S-N* diagram; it is a point *on or below* the diagram.

In the case of tests of metals that do not give an *S-N* diagram which becomes horizontal the following method of estimating endurance limit may be useful. Take one or more specimens which have "run out" without fracture and "step up" the load to give a stress which will cause fracture (specimens "K" and "L," Fig. 8). Then at the raised stress plot the number of cycles at the higher stress necessary to cause fracture. If this number of cycles is well to the *right* of the *S-N* diagram the stress at which the specimen was originally run (as in the case for "K") then there is evidence that the million of cycles previously applied increased the endurance of the metal, and hence the stress first applied to "K" (22,000 lb. per sq. in.) is *below* the endurance limit of the virgin metal. If the number of cycles at the higher stress is to the *left* of the *S-N* diagram (as is the case for "L") then there is evidence that the millions of cycles previously applied decreased the endurance of the metal, and hence the stress first applied to "L" (26,000 lb. per sq. in.) is *above* the endurance limit of the virgin metal. Thus some evidence is given that the value of the endurance limit for Metal "B" in Fig. 8 lies between 22,000 lb. per sq. in. and 26,000 lb. per sq. in.

REPORT OF JOINT RESEARCH COMMITTEE
ON
EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS

PROGRESS REPORT TO THE SPONSOR SOCIETIES

This report presents briefly a review of the activities of the Joint Research Committee for the year ending June, 1935.

Meetings:

Two meetings were held, one at Atlantic City, N. J., in June, 1934, and one at New York City, in December, 1934. Meetings of subcommittees were also held, as required, throughout the year.

Membership:

The Joint Committee records with deep regret the loss of one of its most valued members, John A. Mathews, who died suddenly on January 11, 1935.

Finances:

During the calendar year 1934, an additional contribution of $3000 to the Joint Committee's funds was received from Engineering Foundation, which has made it possible to continue sponsorship of researches at the Battelle Memorial Institute during the year 1935. Procurement of additional funds for the sponsored researches of the Joint Committee is in the hands of a newly organized Committee II on Finances, the chairmanship of which has been accepted by R. A. Bull.

High Temperature Test Methods (Special Committee, N. L. Mochel, chairman):

Subsequent to the June meeting, as mentioned in the report last year, the Joint Committee presented through the A.S.T.M. Committee E-10 on Standards, revisions of the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (E 21 – 33 T) and of the Tentative Method of Test for Long-Time (Creep) High-Temperature

Tension Tests of Metallic Materials (E 22 – 33 T). The revised methods were accepted for publication as tentative by Committee E-10[1] and appear in the 1934 *Proceedings*.[2]

The Tentative Methods E 21 and E 22 have been further reviewed during the past year by the Special Committee composed of F. E. Bash, H. C. Cross, P. E. McKinney, E. L. Robinson, A. E. White and N. L. Mochel. No changes are being recommended at this time in Tentative Method E 21, but since there are several features of this method now under consideration it is recommended that it be continued as tentative in its present form.

Further changes and additions appear desirable, however, in Tentative Method E 22 in line with the revisions made last year. The action taken last year was to make, as the objective or specific purpose of the method, the creation of reliable "time-creep" curves, and to transfer to an appendix all matters pertaining to evaluation or interpretation. It was intended, last year, to transfer Section 12 (*d*) and the last item of Section 12 (*e*) to the appendix but due to an oversight they were allowed to remain. Recommendation is now made for their transfer as stated below.

Last year, Fig. 1 (*b*) was added to the method, approving the use of longer test specimens. A change is recommended at this time dealing with allowable variations of temperature over the gage length of various lengths of specimens.

In keeping with the plan adopted in 1934, a carefully prepared Appendix has been developed for inclusion in Tentative Method E 22 as mentioned below. This Appendix deals with matters of evaluation of the time-creep curves, outlining current practices and well-founded opinions. It is the opinion of the committee that such a presentation will be of considerable value to those interested in the test method.

The committee accordingly recommends that Method E 22 be revised as follows and continued as tentative:

Section 5.—Change Paragraph (*b*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*b*) ***For specimens with 2 in. to 5 in. gage length,*** the design of the furnace shall be such that the maximum variation of temperature over the gage length of the [calibration bar, shown in Fig. 2 (Form No. I) will] ***specimen shall*** not exceed [5] ±*3* F. for temperatures up to and including 1200 F., [10] ±*5* F. for temperatures over 1200 F. and up to and including 1600 F., and [20] ±*10* F. for temperatures over 1600 F. ***For all longer gage lengths, the design of the furnace shall be such that the maximum variation of temperature over the gage length of the specimen shall not give rise to an error in strength in excess of 1 per cent.***

Section 12.—Omit Paragraph (*d*) which reads as follows, relettering Paragraph (*e*) as (*d*):

> (*d*) *Stress-Temperature Curves.*—For plotting stress-temperature curves the following scales shall be used:

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[1] In submitting these revised tentative methods to Committee E-10 on Standards, the Joint Committee reported results of the letter ballot vote as follows: Of a total membership of 16, 15 members returned their ballots, all of whom voted affirmatively.

[2] ***Proceedings,*** Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1214, 1223 (1934); also 1934 Book of A.S.T.M. **Tentative Standards, pp. 1138, 1147.**

SCALE FOR TEMPERATURE (ABSCISSAS)	SCALE FOR STRESS (ORDINATES)
½ in. = 100 F.	1 in. = 10,000 lb. per sq. in.

Curves showing creep rates in the secondary flow period of 0.01, 0.1, 1.0 or 10 per cent per 10,000 hr. shall be plotted.

Omit the last item of Paragraph (*c*), which reads as follows: "Stress-temperature or creep-rate evaluation (see Paragraph (*d*))."

Appendix.—Replace the present Appendix with Appendix II attached hereto.[1]

The above recommendation has been submitted to letter ballot of the Joint Committee, which consists of 15 members, for submission to the sponsor societies; 15 members returned their ballots, all of whom have voted affirmatively.

Committee III on Projects (C. E. MacQuigg, chairman):

The detailed work of this committee is carried out largely through its subcommittees and there follows a brief résumé of activities during the past twelve months:

Subcommittee D (H. J. Kerr, chairman).—In cooperation with the Special Committee on High Temperature Test Methods, this subcommittee has arranged to distribute samples of 0.40 per cent carbon steel to different laboratories. High-temperature tension tests are to be carried out under the conditions outlined in the Tentative Method E 21 – 34 T to establish the adequacy of this test method. Ten or more laboratories will take part in this work on steel which has first been very carefully checked for uniformity. Acknowledgment is made to the Bethlehem Steel Co. for its cooperation in preparing, without cost to the committee, steels suitable for distribution.

Subcommittee E (M. S. Northup, chairman).—Activities similar to those outlined for Subcommittee D have been undertaken by this subcommittee, operating under the Tentative Method E 22 – 34 T. Seven or more laboratories are cooperating in this work.

Subcommittee F (H. W. Gillett, chairman).—Studies of pearlitic unalloyed steel and austenitic nickel-chromium steel, previously reported,[2] indicated that fatigue was unlikely as a cause of failure at temperatures of 1000 F., or above, since the fatigue limits in both classes of steel were above the stresses which could be sustained with small amounts of creep. While broad generalizations are not justified without confirmation for particular cases, there does not now appear to be a pressing need for further studies of the fatigue of steels at high temperatures.

Similarly, fatigue is not ordinarily a problem in service at subatmospheric temperatures. The work of this subcommittee has, therefore, been suspended for the present.

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[1] See p. 1300.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 208 (1934).

Subcommittee N (J. W. Bolton, chairman).—This subcommittee has been engaged in studying methods for the determination of wear and seizure in metals at high temperatures. A report summarizing published data has been under preparation. A prediction cannot be made at this time whether publication of this report will be warranted, but it is expected to be useful in determining what further may be done in extending our knowledge in this field.

Subcommittee O (Jerome Strauss, chairman).—In previous reports of researches on austenitic nickel-chromium steels, attention was given chiefly to the mechanical properties at elevated temperatures. Corrosion tests were undertaken, however, by this subcommittee on samples of these metals and the work is now nearing completion. A report is expected to be available during the latter part of the current calendar year, at which time it will be determined whether publication is warranted.

Subcommittee P (H. W. Russell, chairman).—During March, 1935, as a result of the increasing importance of processes carried out at subatmospheric temperatures, this subcommittee was organized to consider the effects of low temperatures on metals. The subcommittee contemplates preparation of a bibliography, expects to consider the preparation of specifications for making low-temperature mechanical tests and perhaps also to stimulate researches covering those engineering properties which may be adversely affected by subatmospheric temperatures.

Sponsored Researches.—Sponsorship of researches has been continued during the present calendar year at the Battelle Memorial Institute. Work has been continued on the study of embrittlement of austenitic nickel-chromium steels as a result of prolonged exposure to high temperatures and a summary was prepared, following completion of this project, and is included in Appendix I to this report.

The work in question relates to the progressive changes in toughness of an austenitic steel when exposed for long periods to high temperatures, both with and without stress.

Work was initiated on a second project relating to the interpretation of creep tests, the results of which are now broadly utilized by engineers in determining allowable stresses for high-temperature service.

Creep tests, extending over periods of more than several thousand hours are not often made and yet design is frequently based on a service life of 10,000, 20,000 hr., or more. Estimates, when made on the basis of creep tests of several thousand hours duration are extrapolations. It has been felt by some engineers and many of the members of the Joint Committee that it would be desirable to correlate the results of creep tests made under the usual conditions with the performance observed in long exposures to stress at high temperatures, for example, of the order of 25,000 hr

Prolonged creep tests of this sort have been undertaken at the Battelle Memorial Institute, under the sponsorship of the Joint Committee, on a pearlitic unalloyed steel and on an austenitic nickel-chromium steel.

Beginning at the latter part of the current calendar year, periodical progress reports may be expected, provided sufficient funds can be secured for the continuation of the three-year test program involved. Funds are now available to cover the work during the year 1935, and perhaps also part of 1936.

Committee IV on Publications (H. W. Gillett, chairman):

This committee, which prepares data for publication, reviews committee reports, prepares news items and the handling of details incident to the sponsorship by the Joint Committee of technical sessions or papers by individuals, functioned effectively during the past year as it has in the past. Its activities are best indicated by a review of this report and Appendix I.

Committee V on Oil Refinery Problems (H. J. French, acting chairman):

It has been impracticable during the past year to arrive at a program acceptable to all interests represented on this committee. A plan is necessary before funds can be secured for support of research in actual oil refinery service and it has, therefore, not been practicable to build upon the plans outlined when the committee was organized in March, 1933.

The future of this committee and its work will be determined largely during the next six months and will depend, among other things, upon the development of an acceptable plan and the procurement of adequate financial support.

Miscellaneous Activities:

Close cooperation is maintained between the Joint Committee and Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys of the American Society for Testing Materials.

Members of the Joint Committee also have cooperated individually with Subcommittee XXII on Valves, Fittings, Piping and Flanges for High-Temperature Service of the A.S.T.M. Committee A-1 on Steel, and with the Special Subcommittee of the Boiler Code Committee of the American Society of Mechanical Engineers with reference to the effect of temperature on the properties of metals. A considerable amount of time has been devoted to these semiofficial cooperative projects during the past year.

Respectfully submitted on behalf of the Joint Committee,

H. J. FRENCH,
Chairman.

N. L. MOCHEL,
Secretary.

APPENDIX

REPORT ON EFFECT OF LONG-TIME HEATING WITH AND WITHOUT STRESS ON IMPACT RESISTANCE OF 18 PER CENT CHROMIUM, 8 PER CENT NICKEL STEEL (K9 AND K19 STEEL)

Report to the Joint Committee Covering a Sponsored Research Project Carried Out at Battelle Memorial Institute.

It is generally considered a normal behavior for austenitic nickel-chromium steel to lose toughness, as evaluated by the impact test, after long sojourn at temperatures of 1100 to 1400 F. The progress of this "embrittlement" (usually so termed in spite of a final Charpy impact value of 40 ft-lb. or more) was traced for two lots of wrought 18 per cent chromium, 8 per cent nickel steel of 0.06 per cent and 0.085 per cent carbon in the 1932 report of the Joint Research Committee on Effect of Temperature on the Properties of Metals.[1]

In that work standard square Charpy bars, with the keyhole notch, were heated for 1000 hr. at temperatures ranging in 200-deg. steps from 800 to 1600 F. The greatest embrittlement occurred on water-quenched material and at 1400 F. The curve for the lower carbon steel, designated K9c, is shown in Fig. 1. The report concluded with the statement that such notched-bar tests were the necessary starting point for the study of embrittlement, but that they "may not tell the whole story for the actual service conditions under which these steels are often used."

In a later study of creep properties of austenitic stainless steel by the Joint Research Committee, published in 1934,[2] two different lots of similar steels were used which were designated K19. This series of tests included two carbon contents, and both cast and wrought material. Most of the creep tests were made in the temperature range 1000 to 1200 F. After the creep-test specimens had been held under load for extended periods, usually 1000 to 1500 hr. or more, round Izod specimens with a V notch were machined from the test section and broken in impact. (Izod specimens were used because the creep specimens were of too small diameter to afford a standard Charpy specimen, and in order to allow obtaining duplicate impact specimens from the same creep specimen.)

The surprising fact was noted that the low-carbon wrought K19 steel did not show appreciable embrittlement after being held under stress.

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[1] Reports on: Cooperative Study of Charpy Notched-Bar Impact Tests of 18 Per Cent Chromium, 8 Per Cent Nickel, Stainless Steels; Magnetic Permeability Tests of 18 Per Cent Chromium, 8 Per Cent Nickel, Stainless Steels; Structural Stability of 18 Per Cent Chromium, 8 Per Cent Nickel, Stainless Steels at Elevated Temperatures in the Absence of Stress, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 156–192 (1932).

[2] H. C. Cross, "High Temperature Tensile, Creep, and Fatigue Properties of Cast and Wrought High and Low Carbon 18Cr, 8Ni Type Steel from Split Heats," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 56, No. 7, July, 1934, p. 533.

One specimen of water-quenched low-carbon K19 material after 1655 hr. at 1200 F. under stress of 8345 lb. per sq. in., during which test it had extended about 0.6 per cent, showed an Izod value of 99 ft-lb. against an initial value of 101 to 107 ft-lb.

All the other specimens tested at 1200 F. or shorter periods showed equal lack of embrittlement. The same thing was true for the cast material of this heat as well as for the wrought material. Moreover, the higher carbon (0.125 per cent carbon) heat, while losing some toughness under stress, retained far more than was expected, the wrought material after 1100 to 1800 hr. under load at 1200 F. giving 63 to 96 ft-lb. against its initial 103 to 109 ft-lb. Even the cast higher carbon material, although giving some values lower than the wrought, retained, after long loading at 1200 F., 47 to 97 ft-lb. against its initial 93 to 94 ft-lb.

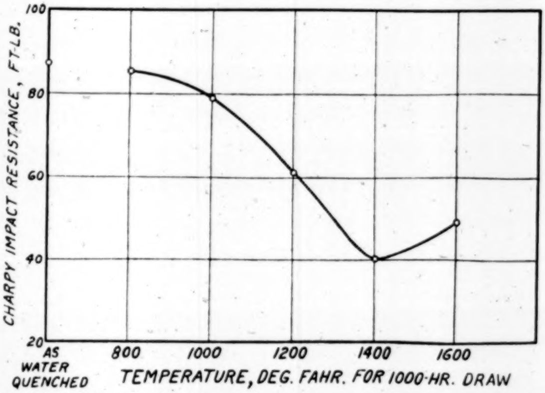

FIG. 1.—Effect of Heating 1000 hr. at Various Temperatures on Charpy Impact Resistance of Wrought 18 per cent Chromium, 8 per cent Nickel Steel (Material K9c, 0.06 per cent Carbon).

Since sojourn at 1400 F. is supposed to produce more embrittlement than at 1200 F., one creep test was run on the 0.125 per cent carbon austenitic chromium-nickel steel at 1400 F. for 665 hr. at 1600 lb. per sq. in., during which test the specimen extended about 0.03 per cent. The Izod impact value was determined after the creep test. It was 93 ft-lb., indicating that no appreciable embrittlement had occurred.

The insensitivity of the second lot of steels (K19) was of particular interest in that these steels had no "stabilizing" additions. Since the chemical composition of the low-carbon steels of the K9 and K19 series differed only in a slightly higher nickel content in material K19, but the behavior of the two steels seemed to be different, it was decided to study material K19 by unstressed impact specimens as had been done with material K9, but to confine the study to 1400 F. and to trace the progress of embrittlement with time, since it had been suggested that the material

K19 creep specimens might have gone through a brittle stage and then recovered.

The similarities and differences of the wrought low-carbon K9 and K19 steels may be summarized as follows:

Material	Chemical Composition, per cent						Mode of Manufacture	Heat Treatment	Impact Value Before Test	Impact Value After 1000 hr. (or more for K19)		
	Carbon	Manganese	Silicon	Chromium	Nickel	Nitrogen				At 1200 F.	At 1400 F.	
K9......	0.06	0.56	0.68	18.0	8.5	not detected	commercial heat not induction melted	water quenched from 2100 F.	87 Charpy, keyhole notch	61	40	*unstressed*
K19.....	0.067	0.50	0.65	18.21	9.56	0.056	induction-furnace heat	water quenched from 2000 F.	101 to 107 Izod, V notch	97 to 111	not determined	*stressed* (*i.e.* after creep)

Five differences might be listed, (*a*) in chemical composition (nickel, nitrogen), (*b*) in melting method, (*c*) in quenching temperature, (*d*) in type of notch, (*e*) in heating with and without stress, or, with and without slight deformation. Of the differences that were under control, it was not thought wise to shift the quenching temperature of material K19 since it had been agreed in the previous study of material K19 that 2000 F. was a preferable temperature and more representative of present practice. It was decided to use the standard square Charpy bar with keyhole notch, identical with that previously used on material K9. An attempt was made to utilize a standard square Charpy bar with a 45-deg. V notch 0.079 in. deep, and such specimens were tested along with the keyhole-notch bars through the first 100 hr. of the "unstressed" test of material K19, in the hope that the V notch would be more selective, but the cross-section back of the notch was so large that the specimens did not break in the 120-ft-lb. impact machine. The use of the V notch was accordingly abandoned since the use of a deeper V notch or a smaller bar would have required a non-standard impact specimen.

The rough-machined K19 bars, $\frac{1}{2}$ in. square, $2\frac{3}{16}$ in. long, cut from a 1-in. wrought rod, were heat treated just as was done for the 2000 F. water-quenched K19 bars previously reported on. The electric muffle furnace was provided with two No. 22 gage chromel-alumel couples, each inserted into a dummy bar, one connected to a controller, the other to a recorder. A temperature survey of the furnace, loaded with dummy specimens with thermocouples in specimens at 9 locations, showed that the temperature was 1400 ± 10 F. The controller held the nominal temperature to 1400 ± 5 F. Calibration of the two thermocouples after completion of the tests indicated that during a portion of the test period, temperatures lower than

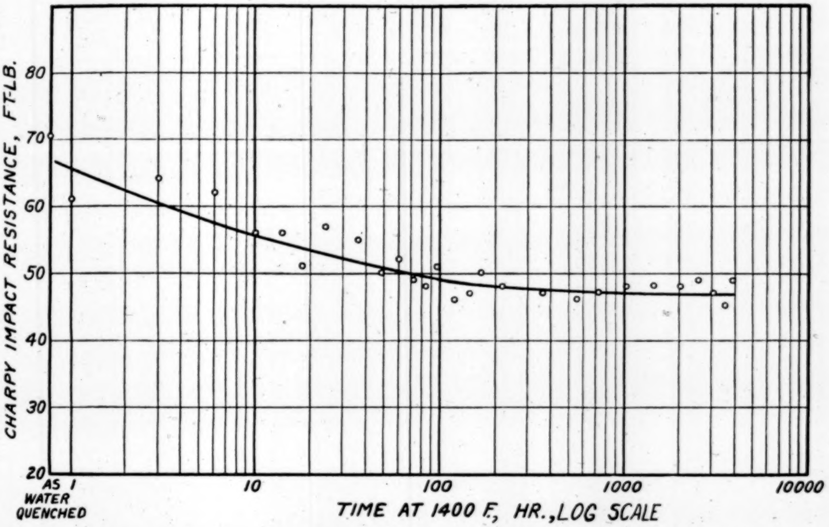

FIG. 2.—Effect of Long-Time Heating at 1400 F. on Charpy Impact Resistance of Wrought 18 per cent Chromium, 8 per cent Nickel Steel (Material K19, 0.067 per cent Carbon).

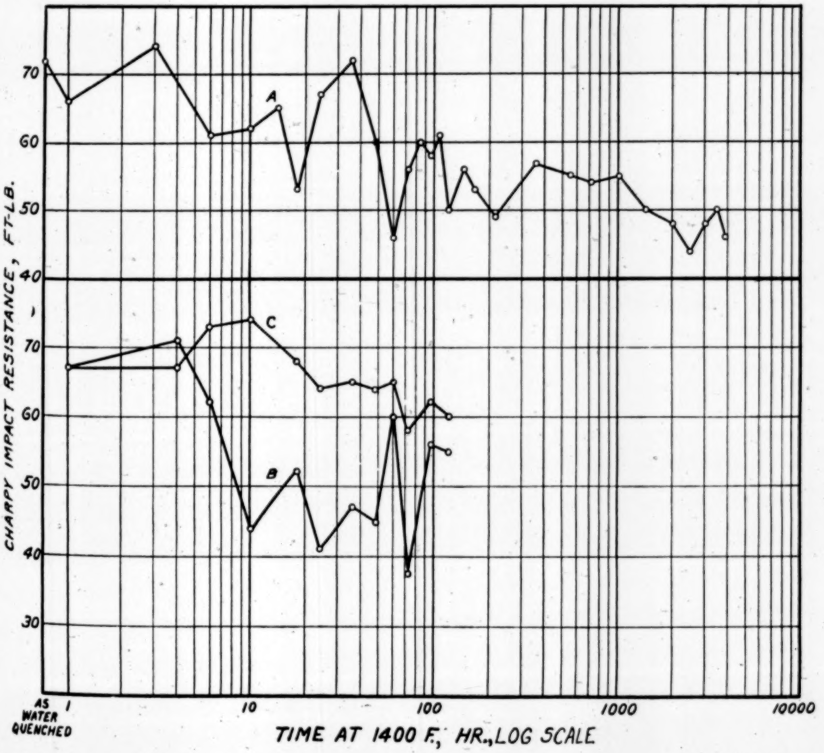

FIG. 3.—Effect of Long-Time Heating at 1400 F. on Charpy Impact Resistance of Cast 18 per cent Chromium, 8 per cent Nickel Steel (Material K19, 0.067 per cent Carbon).

1385 F. may have existed. This deviation however is not in the direction which would tend to decrease embrittlement materially.

The test was run nearly 4000 hr., with a cast and a wrought specimen removed at intervals, machined to the standard square Charpy keyhole bar and broken at room temperature. The results are shown in Figs. 2 and 3. For the wrought K19 material, the impact resistance fell gradually from an initial value of 70 ft-lb. to about 49 ft-lb. at 100 hr., and from 100 hr. to 3868 hr. it remained constant at 46 to 50 ft-lb.

The drop from 79 to 46 ft-lb., or a 35 per cent decrease compares with a drop of 87 to 40 ft-lb. or 55 per cent decrease on material K9. However, the final value is of the same order. Duff[1] has stated that low-carbon 18 per cent chromium, 8 per cent nickel steel drops from 75 to 45 ft-lb. Charpy impact value on 3000 hr. exposure above 1000 F. but does not thereafter decrease.

The wrought K19 material therefore appears to be normal in its impact behavior after heating in air without stress. It "embrittles" in that it loses toughness but it is still tough, for no material with a Charpy value of 40 to 50 ft-lb. can be fairly called brittle. This normal behavior indicates that the behavior of the creep specimens in refusing to embrittle (at least as shown by a V-notch round Izod bar) is probably normal also.

This raises the question whether material under stress and undergoing slow deformation is more resistant to impact embrittlement than that unstressed. The test of impact resistance after creep at 1400 F. on the high-carbon K19 material has previously been referred to, where in 665 hr. under load, the Izod V-notch impact fell only from 106 to 93 ft-lb. It was decided to make a similar test of material K9, but to heat only for 100 hr., since the decrease in unstressed impact value is, according to Fig. 2, practically all accomplished in the first 100 hr. Since no low-carbon K19 material had been so run, a bar of that steel was run also so that both steels were tested alike. Duplicate Izod bars were used as in the creep work reported in 1934.[2] The load was 1600 lb. per sq. in. in both cases. Loading and heating were carried on in the creep-test equipment. The results are as follows:

	IZOD VALUES AS HEAT TREATED, FT-LB.	IZOD VALUES AFTER 100 HR. AT 1400 F. AT 1600 LB. PER SQ. IN., FT-LB.
Material K9	105 to 108	103 to 108
Material K19	112 to 109	99 to 108

The evidence indicates that material K19 is not peculiar in showing but slight loss of toughness when stressed as against a measurable loss when unstressed. Embrittlement may thus be slower in actual service than in an unstressed laboratory test. Thompson and Van Duzer[1] report the following results on specimens taken from 18 per cent chromium, 8 per cent nickel tubing in high-temperature steam service. Specimens after 3000, 10,000, and 15,000-hr. service at 1100 F. (besides several thousand hours at lower temperatures, mainly at 1000 F.) lost respectively 5, 17½ and 68 per cent of their nominal initial Izod impact values.

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[1] R. L. Duff, "Petroleum Refineries, "Section A of Chapter 18 of volume by E. E. Thum entitled "The Book of Stainless Steels," First Edition, p. 487 (1933).

[2] *Loc. cit.*

Unfortunately the exact values in foot-pounds are not given, and the percentage loss is based on an assumed initial value for the type alloy, not on the same specimens. The specimens varied in carbon from 0.05 to 0.09 per cent and were obviously not identical. The stresses imposed on these tubes in service are not stated. Their data are cited lest it be assumed without proof that stress necessarily permanently inhibits embrittlement. That it tends to delay it seems to be indicated by the laboratory impact data recorded above.

Cast Material.—As stated above, impact specimens of cast as well as wrought K19 were carried through the 3868-hr. heating period at 1400 F., and removed at intervals. The results were quite erratic, although the general trend was similar to that of the wrought specimens. Figure 3, curve *A*, shows the results. The specimens had been taken without special regard to their location in the "teeth" of the multiple keel-block casting. As was shown by the photomacrographs in the 1934 report[2] these teeth were very coarse grained due to slow freezing, and varied in structure from columnar to equiaxed grains.

Another series of cast specimens was than heated for 120 hr. Specimens were removed and broken at intervals as before, in which one set was taken across the section so that the notch and breaking section were in equiaxed grains, and the other set from the tooth face with columnar grains. The wide scatter of the latter, curve *B*, indicates that the erratic values were due to grain size and orientation, to which an impact test is known to be sensitive.

The smoother curve, curve *C*, for the specimens with more nearly equiaxed grains indicates that the fluctuations in the tests of cast material are not due to variations in the degree of embrittlement, but that the effect of grain orientation is large in comparison to the embrittling effect.

SUMMARY

Cast and wrought 18 per cent chromium, 8 per cent nickel steel (K19) shows moderate loss of impact resistance after heating 100 hr. at 1400 F. and only minor changes in impact resistance with further heating up to 3870 hr. A satisfactory impact resistance remained after 3870 hr. heating at 1400 F.

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[1] P. W. Thompson and R. M. Van Duzer, Jr., "High Temperature Steam Experience at Detroit," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 56, No. 7, July, 1934, p. 497.

[2] *Loc. cit.*

The K19 steel showed after 1000 hr. heating at 1400 F., a lower percentage reduction than shown by steel K9 in the 1932 tests[1] but came down to about the same value.

Heating at 1400 F. for 100 hr. under stress produces little loss of impact resistance for two 18 per cent chromium, 8 per cent nickel steels (K9 and K19).

The data suggest that embrittlement, measured by impact resistance, may go on at a slower rate in a stressed than in an unstressed specimen.

Respectfully submitted on behalf of the committee,

H. C. CROSS,
F. B. DAHLE.

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[1] *Loc. cit.*

REPORT OF COMMITTEE B-1

ON

COPPER WIRE

Committee B-1 on Copper Wire held two meetings during the year; in New York City on January 21, 1935, and in Philadelphia, Pa., on March 4, 1935.

At the January meeting, the committee adopted by a rising vote the following resolution concerning the death of Vice-Chairman W. H. Bassett, Sr.:

> BE IT RESOLVED by Committee B-1 on Copper Wire of the American Society for Testing Materials that in the death of Vice-Chairman W. H. Bassett, Sr., a member of this committee since its organization and at the time of his death President of the Society, the Committee and the Society as a whole has sustained a loss which it is the desire of this committee to record. Through his helpful and directing influence, Mr. Bassett has contributed in great part to the work of the committee. Through his kindly personal contacts he has endeared himself to each member of the committee and individually the members desire to express their sense of loss in his untimely passing.

A copy of this resolution has been sent to Mrs. Bassett at her home in Cheshire, Conn.

Mr. W. H. Bassett, Jr., was elected Vice-Chairman of the committee for the remainder of the term.

Committee B-1 has concerned itself with revisions of the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 27), for Bronze Trolley Wire (B 9 – 32), and for Copper Trolley Wire (B 49 – 26); also considerations looking toward a revision of the Tentative Specifications for Hard-Drawn Copper Transmission Cable (B 87 – 32 T). Substantial progress has been made in all of these matters.

The Subcommittee on Electric Transmission Wire and Cable Specifications (G. E. Dean, acting chairman) has been active in accumulating basic data as to the effect of soft *versus* hard center wires in hard-drawn concentric cables. Much valuable research work on this subject has been done by two of the manufacturers in connection with the work of the subcommittee. It has been determined that the use of a hard center wire or core is not prejudicial to good mechanical performance of the entire cable. This work has consumed much time and it has not been possible to complete recommendations for desirable modifications in the Tentative Specifications for Hard-Drawn Copper Transmission Cable (B 87 – 32 T).

RECOMMENDATIONS AFFECTING STANDARDS

Standard Specifications for Bare, Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (*B 8 - 27*).[1]—There has been much need for a revision and amplification of these standard specifications. The committee has succeeded in correlating the requirements of the Sectional Committee on Insulated Wires and Cables and of the Insulated Power Cable Engineers Association as well as of the membership of Committee B-1 itself in the preparation of a new stranding table for concentric-lay cables. While the preparation of a definite schedule of other types of cable has been deferred, the committee has agreed on modifications in the wording of the specifications so that other than concentric-lay cables may be constructed without necessary conflict. Thus, the scope of the specifications is considerably enlarged and they become more generally applicable to cable manufacture. The requirements of users of hard-drawn and medium-hard-drawn bare conductor for use on overhead lines has been carefully considered, and greater restrictions have been placed on the use of brazes in such cable. There has arisen a very definite industry demand for the testing of cable in its completed form, while present specifications provide only for the testing of the individual wires of hard-drawn or medium-hard-drawn cable before cabling. Changes agreed to by the committee provide for the testing of the completed cable as an alternative to the testing of individual strands before cabling, and specify the necessary limits of variation in tensile strength requirements when this test is employed. Certain modifications of an editorial nature also have been made by the committee. These various changes have been incorporated in the proposed Tentative Specifications for Bare, Stranded Copper Cable: Hard, Medium-Hard or Soft, appended hereto,[2] which the committee recommends be issued for at least a year as a tentative revision of the present Standard Specifications B 8 - 27, the latter to remain in effect for the present.

Standard Specifications for Bronze Trolley Wire (*B 9 - 32*).[3]—The Joint Committee on Trolley Wire Specifications, representing the Association of American Railroads, The American Transit Engineering Association and the A.S.T.M. through Committee B-1, has recommended that there be included in these specifications provisions for a third class of bronze trolley wire having a higher conductivity than the two classes now included and of intermediate strength, and that the types of bronze wire be referred to according to conductivity rather than according to strength. The Joint Committee also recommended that certain permissible variations be provided for the dimensional requirements of the standard sections of grooved trolley wire since the present specifications do not indicate such limits

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 746.

[2] See p. 736.—ED.

[3] 1933 Book of A.S.T.M. Standards, Part I, p. 757.

These various modifications have been incorporated in the proposed Tentative Specifications for Bronze Trolley Wire, appended hereto,[1] which the committee recommends be issued for at least a year as a tentative revision of the present Standard Specifications B 9 – 32, the latter to remain in effect for the present.

Standard Specifications for Copper Trolley Wire (B 47 – 32).[2]—The committee believes that provisions should be made in these specifications also for permissible variations in the dimensional requirements of the standard sections of grooved trolley wire, the same as those to be provided above for bronze trolley wire. These dimensional tolerances have been incorporated in the accompanying Fig. 1, appended hereto,[3] which it is recommended be published as tentative for a year to replace, when adopted, the present figure in the Standard Specifications B 47 – 32.

The above recommendations have been submitted to letter ballot of the committee, which consists of 29 members; 26 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED REVISIONS OF STANDARDS			
Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 27)	22	1	3
Standard Specifications for Bronze Trolley Wire (B 9 – 32)	21	0	5
Standard Specifications for Copper Trolley Wire (B 47 – 32)	21	0	5

This report has been submitted to letter ballot of the committee, which consists of 29 members; 23 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. A. CAPP,
Chairman.

J. H. FOOTE,
Secretary.

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[1] See p. 740.—ED.
[2] 1933 Book of A.S.T.M. Standards, Part I, p. 752
[3] See p. 743.—ED.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS

Committee B-2 on Non-Ferrous Metals and Alloys held two meetings during the year, in Atlantic City, N. J., on June 27, 1934, and in Philadelphia, Pa., on March 5, 1935.

Subsequent to the 1934 annual meeting, as mentioned in the report of the committee last year,[1] the committee presented to the Society through Committee E-10 on Standards revisions of the Standard Specifications for Pig Lead (B 29 – 23) in the form of new tentative specifications to replace the standard specifications which were recommended to be withdrawn. The tentative specifications were accepted for publication[2] by Committee E-10 at a meeting on August 22, 1934, to replace the standard and appear in the 1934 *Proceedings*.[3] Since the new tentative specifications were intended to supersede the Standard Specifications B 29 – 23, the proposed withdrawal of the standard was also approved by Committee E-10.

RECOMMENDATIONS AFFECTING STANDARDS

In this report the recommendations affecting standards and tentative standards are noted in brief form below, together with the results of the letter ballot. These recommendations are explained in the reports of the subcommittees directly responsible for them.

I. Proposed Tentative Standard.—The committee recommends that the proposed Tentative Specifications for Lead-Coated Copper Sheets, as appended hereto,[4] be accepted for publication as tentative.

II. Proposed Revision of Existing Standard.—The committee recommends for publication as tentative, a revision of the Standard Specifications for Slab Zinc (Spelter) (B 6 – 33) which will make provision for zinc of extreme purity as grade (*1 a*) Special High Grade. The detailed changes, prepared by Subcommittee I on Pure Metals in Ingot Form, appear later in this report under Activities of Subcommittees.

III. Adoption of Tentative Standards as Standard.—The committee recommends that the following tentative standards be referred to letter ballot of the Society for adoption as standard:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 217 (1934).

[2] In submitting the tentative specifications to Committee E-10 on Standards, Committee B-2 reported results of the letter ballot vote as follows: Of a total membership of 99, 52 members returned their ballots of whom 33 voted affirmatively, 2 negatively and 17 marked their ballots "not voting."

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 662 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 155.

[4] See p. 746.—Ed.

Tentative Specifications for Pig Lead (B 29 – 34 T), with correction of typographical error, and

Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 33 T), as revised.

IV. Adoption as Standard of Tentative Revision of Existing Standard.—The committee recommends that the tentative revision in the Standard Methods of Chemical Analysis of Manganese Bronze (B 27 – 19) published since 1928 be referred to letter ballot of the Society for adoption as standard.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 103 members; 73 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Specifications for Lead-Coated Copper. Sheets	52	0	21
II. PROPOSED REVISION OF STANDARD			
Specifications for Slab Zinc (Spelter) (B 6 – 33)	58	0	15
III. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Pig Lead (B 29 – 34 T)	51	1	21
Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 33 T), as revised	46	0	27
IV. ADOPTION AS STANDARD OF TENTATIVE REVISION OF STANDARD			
Methods of Chemical Analysis of Manganese Bronze (B 27 – 19)	49	0	24

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Pure Metals in Ingot Form (T. A. Wright, chairman).—The honorary chairman of Committee B-2, Mr. William Campbell, appointed Mr. H. C. Jennison to act as temporary chairman of this subcommittee *vice* Mr. W. H. Bassett, deceased. At a meeting of the subcommittee in Philadelphia on March 4, 1935, Mr. T. A. Wright was elected as chairman.

Attention is called to a typographical error appearing in the note to Section 6 of the Tentative Specifications for Pig Lead (B 29 – 34 T) as published in the 1934 Book of A.S.T.M. Tentative Standards, page 156, wherein the analysis of common lead (Grade IIIa) was quoted incorrectly. The note in its proper form which reads as follows, appeared correctly in the specifications as published in the *Proceedings*, Vol. 34, Part I, page 663 (1934):

> NOTE.—Common Lead (Grade IIIa) conforms to the above analysis except that bismuth shall not be over 0.25 per cent and the total purity shall not be less than 99.73 per cent lead.

The subcommittee recommends that the Tentative Specifications for Pig Lead (B 29 – 34 T) as corrected be adopted as standard.

The subcommittee also recommends for publication as tentative the following revisions in the Standard Specifications for Slab Zinc (Spelter) (B 6 – 33).[1] These modifications are proposed in order that the specifications will conform to present-day practice, especially as regards zinc of extreme purity:

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 1. These specifications cover [Virgin Spelter, that is,] slab zinc (spelter) made from ore or [similar raw] *other* material by a process of [reduction and] distillation or by electrolysis, and not produced [from reworked metal] *by "sweating" or remelting of secondary zinc*, in six grades, as follows:
>
> (1a) Special High Grade
> (1) High Grade
> (2) Intermediate
> (3) Brass Special
> (4) Selected
> (5) Prime Western

Section 2.—Change to read as follows by the omission of the words in brackets:

> 2. A brand shall be cast in each slab by which the maker [and grade] can be identified.

Section 4.—In the table of requirements as to chemical composition change the lead content for Special High Grade Zinc (Grade *1a*) from "0.010 per cent" to read "0.007 per cent"; also change the iron content for High Grade Zinc (Grade *1*) from "0.03 per cent" to read "0.02 per cent."

Section 8.—Change to read as follows by the addition of the italicized words:

> 8. Where the slab zinc (spelter) satisfies the chemical and physical requirements of these specifications, it shall not be condemned *for defects in manufacturing*, for defects of alloys in which it is used, or for defects in the coating of galvanized products.

Subcommittee VII on Methods of Sampling and Chemical Analysis (H. V. Churchill, chairman).—The Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (B 18 – 21), of Gun Metal (B 28 – 19) and Methods of Battery Assay of Copper (B 34 – 20), which were prepared by this subcommittee and approved as American Tentative Standards some years ago by the American Standards Association, had been suggested for possible submission to the A.S.A. for advancement to the status of American Standards. On investigation, however, each was found to be questionable in one or more particulars and the subcommittee recommended that the submission of these methods to the A.S.A. be held in abeyance pending further consideration. Projects are being organized for the perfection of methods for chemical analysis of special high grade slab zinc and zinc-base alloy die castings.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 858.

An extended research has been undertaken to determine the accuracy of the method for determining silicon in aluminum and aluminum alloys, as contained in the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 33 T).[1] It has been suggested that another method, recommended by Mr. L. H. Callendar of England, by means of solution in sodium hydroxide would give more precise results. At the conclusion of this study it was found that the A.S.T.M. method (tri-acid method) checked the more tedious sodium hydroxide method in all commercial aluminum alloys tested except the aluminum-magnesium alloys, wherein the sodium hydroxide method yields higher results.

Since Methods B 40 – 33 T are intended to be used in conjunction with material specifications, and the aluminum-magnesium alloys are not now covered by A.S.T.M. specifications, the subcommittee recommends that these methods be revised as follows and adopted as standard:

Section 2.—Add a new note as Note 4 to read as follows:

NOTE 4.—In analyzing aluminum alloys containing considerable magnesium, the above method will give somewhat low results for silicon.

The subcommittee also recommends that the tentative revision[2] of the Standard Methods of Chemical Analysis of Manganese Bronze (B 27 – 19) be adopted as standard since this revision has been tentative since 1928 and no criticisms of it have been received.

Subcommittee XIII on Strip Zinc (E. H. Bunce, chairman).—This subcommittee has had under consideration the submission of the Standard Specifications for Rolled Zinc (B 69 – 29) to the American Standards Association for approval as American Standard. It was found inadvisable to submit these specifications in their present form and revisions have been suggested and are now under discussion.

Subcommittee XVI on Coated Metals (W. G. Schneider, chairman).—This subcommittee held a meeting at Atlantic City, N. J., in June, 1934, and considered, section by section, a tentative draft of Specifications for Lead-Coated Copper Sheets which were subsequently submitted to letter ballot of the subcommittee and approved. In view of the fact that these specifications are urgently needed by the building industry and in order to circulate them before the spring expansion in construction activities, the Advisory Committee of Committee B-2 approved the specifications for publication as information and they appeared in the January issue of the A.S.T.M *Bulletin*. The subcommittee now recommends that the specifications, as appended hereto,[3] be accepted for publication as tentative.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 620 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 188.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1261 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1189.

[3] See p. 746.—ED.

REORGANIZATION

The committee appointed at the meeting in June, 1934, nominated for chairman of Committee B-2, to succeed Mr. William Campbell who is now honorary chairman, Mr. R. F. Mehl who was duly elected by letter ballot of the committee to that office.

The Advisory Committee has extensively discussed the desirability of reorganizing the activities of Committee B-2. The following three subcommittees whose activities have been assumed by other A.S.T.M. committees have been discharged, and Committee B-2 has recorded in its minutes and acknowledges in this report its indebtedness to members thereof for their volunteer services; namely, Subcommittee IX on Nomenclature of Metals and Alloys, Subcommittee X on Methods of Testing and Subcommittee XII on Metallic Fluxes and Deoxidizers. A definite plan of reorganization has been formulated and is under discussion, whereby the matters under proper scope of Committee B-2 shall be in charge of a number of small subcommittees, each interested in a definite metal or metallurgical product, the new grouping to be made in a manner parallel to present trade practices rather than according to a more logical or scientific classification.

This report has been submitted to letter ballot of the committee which consists of 103 members; 71 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. F. MEHL,
Chairman.

E. E. THUM,
Secretary.

REPORT OF COMMITTEE B-3
ON
CORROSION OF NON-FERROUS METALS AND ALLOYS

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys has been active during the past year through its Subcommittees VI, VII and VIII, primarily in carrying forward the programs of corrosion tests in the field under the sponsorship of those subcommittees.

The 1932 report[1] of the committee gave complete information with regard to the materials being studied by these subcommittees in their tests and described in detail the program of tests planned by each. The 1933[2] and 1934[3] reports of the committee gave results of service tests completed during those years.

Subcommittee VI on Atmospheric Corrosion (W. H. Finkeldey, chairman).—Subcommittee VI presented its report of results obtained after one year of atmospheric exposure on some 24 non-ferrous metals and alloys in the 1933 report of this committee. This subcommittee's program of atmospheric exposure of these various materials has continued and a similar report is included in this year's report.

Subcommittee VII on Corrosion in Liquids (A. J. Phillips, chairman).—Considerable progress has been made in the test program of Subcommittee VII and appended hereto is a detailed report of this subcommittee.

Subcommittee VIII on Galvanic and Electrolytic Corrosion (C. L. Hippensteel, chairman).—The testing program of Subcommittee VIII has also progressed and this subcommittee has prepared a report, appended hereto, which contains detailed data obtained from studies after the second period of exposure under its program.

This report has been submitted to letter ballot of the committee, which consists of 54 members; 29 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

T. S. Fuller,
Chairman.

Sam Tour,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats. Vol., 32, Part I, p. 201 (1932).
[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 232 (1933).
[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 221 (1934).

REPORT OF SUBCOMMITTEE VI ON ATMOSPHERIC CORROSION OF NON-FERROUS METALS AND ALLOYS

This report presents results of the atmospheric corrosion tests on the 24 non-ferrous metals and alloys after an exposure of approximately three years. The same test procedures were followed as were used in the previous tests after one year's exposure,[1] namely, corrosion was determined by:

1. Measuring the change in weight on duplicate 9 by 12-in. plate specimens;
2. Making tension tests to find a change in tensile strength and percentage of elongation; and
3. Making a visual examination of the 9 by 12-in. plates.

A full description of the metals and alloys included in this test appears in the 1932 report of Committee B-3.[2]

CHANGE IN WEIGHT TESTS

The 9 by 12-in. plates were weighed just as they were taken from the test racks without attempting to remove any accumulations of corrosion products. The weight determinations were made by the Division of Metallurgy of the National Bureau of Standards, using a balance sensitive to 0.1 mg. However, the weights of the plates are reported only to 0.01 g.

Since no standard units have been adopted as yet by the subcommittee for reporting weight changes, this report shows only the total weight changes in grams for each 9 by 12-in. plate, prefixed by a plus or minus sign to indicate a gain or loss. For purposes of comparison the weight changes after the first year's exposure as previously reported in the 1933 report of Committee B-3 have been included in this report. These weight changes can be converted to the units in common use by reference to the tabulation of critical data and the table of densities published in the committee's report for 1933.[1]

With the weight change data from only two test periods available at this time no accurate determination of the corrosion rate can be made for the majority of the materials at most locations. In a number of cases the weight changes still appear as "gains," although a comparison between the first year and third year weight change data shows that with the exception of aluminum and the aluminum alloys, tin, tin bronze, and manganese bronze, the rest of the materials have ceased gaining and are now losing weight. This is true at most locations except La Jolla, where an accumulation of salts and corrosion products is still in progress on practically all materials. The "losses" in weight are greatest in the industrial locations and most severe in New York City.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 234 (1933).
[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 214 (1932).

In the committee's opinion, even a qualitative estimation of the corrodibility of the various materials in the different atmospheres based *only* on the weight change data would be of doubtful value at this time.

Tension Tests

The tension tests were made by the same industrial laboratories which made the first set of tests after one year's exposure. The same test procedure was followed and in practically all cases the tests were made on the same machines.

The data from tension tests made on specimens exposed for three years are given in the appended tabulations together with the percentage change in these properties for both the 1-yr. and 3-yr. test periods. The complete tension test data for the tests after one year's exposure appear in the 1933 report.[1]

Table I.—Length of Exposure Periods at Various Test Locations.

Location	9 by 12-in. Plate Specimens						Tension Specimens			
	First Period		Second Period		Total Exposure Time		First Removal		Second Removal	
	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years
No. 1. Pittsburgh, Pa.......	428	1.17	622	1.71	1050	2.88	428	1.17	1154	3.16
No. 2. Altoona, Pa.........	438	1.20	607	1.66	1045	2.88	438	1.20	1148	3.14
No. 3. State College, Pa....	422	1.15	642	1.76	1064	2.91	422	1.15	1170	3.21
No. 4. New York City.....	456	1.25	627	1.72	1083	2.97	456	1.25	1205	3.30
No. 5. Sandy Hook, N. J...	470	1.29	626	1.72	1096	3.01	470	1.29	1198	3.28
No. 6. Rochester, N. Y.....	265	0.73	615	1.69	880	2.42	420	1.15	1145	3.14
No. 7. Key West, Fla......	416	1.14	632	1.73	1048	2.87	416	1.14	1145	3.14
No. 8. Phoenix, Ariz.......	389	1.06	623	1.71	1012	2.77	389	1.06	1111	3.04
No. 9. La Jolla, Calif.......	380	1.04	614	1.68	994	2.72	380	1.04	1101	3.02

In calculating the percentage change in tensile properties, the same procedure was followed as was used in the first tests, namely, the change in tensile strength or percentage elongation was determined by subtracting the results of the corroded specimens from the results of the test on the storage sets or *vice versa*, depending on which was the larger, reporting the results in the tables as the percentage change referred to the storage set values as a base. The figures appearing in the tables under the heading "Percentage Change in Tensile Properties" are, therefore, net change in properties due to corrosion plus whatever differences exist between the aging in storage and the aging under exposure conditions.

A statistical analysis has been made of the two sets of tensile data, that is, the results of the test made after 1 yr. and after 3 yr. exposure, following the methods recommended in the Manual on Presentation of

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, pp. 244–251 (1933).

Data.[1] The study was made to determine what part of the changes in the tensile properties are due to chance variations in (1) the original materials, (2) the testing methods and machines, (3) the aging properties as distinguished from changes in the tensile properties due entirely to *corrosion.* By statistical analysis methods then, any percentage *loss* in tensile strength or elongation greater than the figures italicized in parentheses in the tabulations representing maximum percentage difference due to chance[2] should be attributable to corrosion. As explained below, however, certain factors affecting these methods of analysis may introduce errors which limit the reliability of the method.

It will be noticed that in some instances the 1-yr. and 3-yr. results (percentage change in tensile properties), when considered with their respective "maximum percentage difference due to chance" values, are not consistent, indicating that all of these differences have not been covered by our calculations. The wide fluctuations in the "difference due to chance" values are also noticeable; and often inexplicable. Larger chance errors in uncorroded than in corroded specimens, especially, are hard to understand. This may be the result of basing the calculations on too few individual tests, of too great variations in materials or test methods to permit classification of the data as homogeneous (that is, produced under controlled conditions), or of the failure in sampling to make each group (of six) typical of the entire lot. In which case, the formulas used in our calculations could not be applied to a statistical study of the test data without reservations.

A review of the tensile strength and elongation percentage change figures for both the 1-yr. and 3-yr. tests, giving due regard to the "maximum percentage difference due to chance" values, shows that so far only a few of the materials have experienced a *large* amount of corrosion in either the industrial or marine atmospheres. The corrosion of all metals and alloys was negligible in rural atmospheres. However, in many cases sufficient corrosion has occurred to permit rough classifications of the materials into several groups based on their corrodibility as indicated by the tensile data.

Although it would be desirable at this time to discuss those materials which already show a substantial amount of corrosion, it is difficult to do so without making the comment unduly long and, furthermore, it runs the danger of placing too much emphasis on certain of the test results without

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[1] Manual on Presentation of Data, sponsored by Committee E-1 on Methods of Testing, *Proceedings,* Am. Soc. Testing Mats., Vol. 33, Part I, p. 451 (1933); also published in pamphlet form.

[2] The maximum percentage difference due to chance is determined according to the following formula:

$$\text{Maximum Percentage Difference Due to Chance} = \frac{3\sqrt{\dfrac{\sigma x^2 + \sigma s^2}{6}}}{\bar{X}s} \times 100$$

where σx = the standard deviation for the tension test result at each particular location.
σs = the standard deviation for the tension test results on the "storage" specimens.
Xs = the average of the tensile test results on the "storage" specimens.

Table II.—Summary of Changes in Tensile Properties After 1 yr. and 3 yr. Exposures.

Figures indicate percentage change (loss only) beyond the variation due to chance, those less than 1 per cent not given.

Material		Pittsburgh				Altoona				New York City				Rochester				Sandy Hook				Key West				La Jolla				State College				Phoenix			
		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation		Tensile Strength		Elongation	
		1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr.	1 yr.	3 yr
Copper and copper alloys..........	A	....	2	....	2	....	2	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....
	B	1	2	2	....	1	3	2	....	1	3	....	....	....	....	....	....	2	1	....	....	....	....	....	....	....	2	....	....	....	....	2	....	....	....	1	....
	C	....	1	....	....	....	2	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....
	D	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	F	....	3	....	....	....	2	....	....	....	2	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	K	....	5	...[a]	...[a]	3	9	...[a]	...[a]	....	13	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	8	19	33[a]	34[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]
	L	....	2	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	M	2	8	....	....	....	6	....	2	4	10	....	5	....	....	....	....	1	2	....	....	....	....	....	....	2	2	....	....	....	....	....	....	....	....	....	....
	N	....	3	....	....	....	7	....	....	....	2	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	P	2	....	....	....	....	3	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Q	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	....	....	....	....	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]
Aluminum and aluminum alloys....	G	....	....	6	10	....	....	2	6	....	....	13	17	....	....	1	5	....	....	8	12	....	....	....	5	....	3	63	64	....	....	....	....	....	....	....	....
	I	2	3	7	...[a]	1	4	5	....	....	4	23	5	....	....	....	....	....	2	....	...[a]	....	....	....	...[a]	....	4	28	47	....	....	....	....	....	....	....	...[a]
	O	2	5	17	26	3	7	28[a]	36	5	6	34	42	....	3	10	20	5	1	30	26	1	2	23	24	30	29	81	82	....	....	....	....	....	....	....	....
	Z	1	4	12	12	....	6	14	27	3	5	28	29	....	....	4	14	2	3	20	27	....	....	21	24	16	19	70	72	....	1	....	....	....	....	6	4
	FF	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	...[a]	....	....	....	....	....	....	....	....	....	....	....	...[a]
Nickel and nickel alloys..........	S	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	T	....	2	....	....	....	4	....	....	....	2	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....
Lead, lead-antimony alloy and tin....	U	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	2	....	....	....	....	....	....	....	....	....
	CC	....	....	....	....	....	1	....	2	....	....	2	....	....	....	....	....	....	2	2	....	....	2	3	2	....	1	....	1	....	....	....	....	....	4	2	....
	EE	....	....	...[a]	...[a]	....	3	...[a]	...[a]	....	....	...[a]	...[a]	....	....	...[a]	...[a]	....	2	...[a]	18[a]	....	....	...[a]	...[a]	....	3	26[a]	47	....	....	...[a]	...[a]	....	....	...[a]	...[a]
Zinc..............	AA	4	4	....	3	1	6	...[a]	....	2	5	4	...[a]	....	....	2	12	....	2	...[a]	....	....	....	...[a]	....	7	6	51[a]	52	....	1	...[a]	....	....	....	...[a]	....
	BB	2	3	....	2	1	3	2	9	2	4	....	3	....	....	....	4	....	....	....	2	....	....	....	....	4	5	1	31	....	....	....	....	....	....	....	....
	HH	....	4	....	....	4	5	3	7	2	3	....	7	....	....	....	....	....	....	....	....	....	....	....	1	2	6	6	31	....	....	2	....	....	....	....	....

[a] The "maximum percentage difference due to chance" value is 15 per cent or greater.

TABLE III.—SUMMARY OF METEOROLOGICAL DATA AT TEST LOCATIONS.

Test Location	Type of Exposure	Elevation Above Sea Level, ft.	Temperature, deg. Fahr.				Precipitation, in.				Snowfall, in.			Number of Days Precipitation (rain or snow), 0.01 in. or over			Relative Humidity, per cent			Sunshine, per cent of Possible			Wind, Average Hourly Velocity, m.p.h., and Prevailing Direction		
			Mean Annual	Mean 1931	Mean 1932	Mean 1933	Yearly Average	1931 Total	1932 Total	1933 Total	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933
No. 1—Pittsburgh....	Industrial	842	.....	55	53.5	53.6	36	39	25.9	40.3	16	19.5	20.6	176	133	140	73	66	68	54	58	50	8.7 W	10.0 W	10.05 W
No. 2—Altoona.......	Industrial	1615	49	.....	50	50	36	.....	38	51	....	44	31	....	129	156	....	....	....	....	....	....	....	W	W
No. 4—New York City	Industrial	150	52	55	54	54	43	35	39	50	7	13	28	151	116	129	66	63	67	62	62	57	13.4 NW	15.1 NW	14.2 NW
No. 6—Rochester.....	Industrial	523	48	51	49	50	33	31	40	26	63	79	57	154	168	160	70	68	66	50	48	46	8.7 W	9.2 W	8.8 W
No. 5—Sandy Hook...	Sea Coast	22	52	55	54	.....	47	32	36	....	4	12	....	116	121	...	73	71	...	55	58	...	12.7 W	14.6 W	....
No. 7—Key West.....	Sea Coast	22	77	76	78	78	38	51	40	52	0	0	0	119	119	105	77	74	76	66	70	70	9.1 E	9.7 E	9.9 E
No. 9—La Jolla.......	Sea Coast	50	61	64	61	60	10	15	11	8	0	0	0	48	40	40	75	74	75	67	65	67	6.6 W	6.5 W	6.4 NW
No. 3—State College..	Rural	1217	48	52	50	51	39	34	38	44	24	30	28	113	117	149	....	....	....	....	....	....	....	W	W
No. 8—Phoenix.......	Rural	1108	70	72	71	71	8	10	7	7	0	0	0	38	37	37	38	34	34	84	84	84	6.0 E	6.1 E	6.0 E

giving due consideration to the corrosion idiosyncrasies of the individual materials.

In lieu of such written comment, Table II has been prepared in which the amount of corrosion shown by the materials is classified as "negligible" (left blank in the tables) if the differences between the "percentage change" figures and their respective "maximum percentage difference due to chance" values are less than 1 per cent, and classified as "small" (indicated by *s*) if the differences are from 1 to 3 per cent and as "significant" (indicated by *X*) if the differences are 3 per cent or greater.

VISUAL INSPECTION OF THE CORRODED PLATE SPECIMENS

The corroded 9 by 12-in. plates were inspected at the Bureau of Standards at the meeting of the subcommittee on November 14, 1934. The appearance of the various materials at each test location after three years exposure is briefly described under "Remarks" in the tabulations.

In these descriptions the term "tarnish" is used to designate a very thin layer of corrosion products. Similarly the term "film" is used for corrosion products of moderate thickness, and the term "scale" for very thick layers of corrosion products.

A reddish brown colored deposit in the form of fine specks was noticed on all the plate and tensile specimens at the Altoona exposure. Since this deposit was found on some of the white metal alloys whose corrosion products are not colored under any ordinary conditions of exposure, it is fairly certain that the reddish deposit is of some foreign origin. A spectroscopic examination of the specks shows them to contain iron oxide, which strongly suggests that they might have resulted from some nearby spray painting operation using an iron oxide pigmented paint. Since in most cases the specks are very fine and well dispersed, it is hoped that their presence will not seriously influence the normal corrosion of the test materials at this location.

TEST ATMOSPHERES

In the tabulations of test data the results from locations having a similar type of atmosphere are grouped together: namely, *Industrial.*—Pittsburgh, Altoona, New York City, and Rochester; *Sea Coast.*—Sandy Hook, Key West, and La Jolla; and *Rural.*—State College and Phoenix. The test data secured so far indicate that New York City is the most corrosive of the industrial type atmospheres and La Jolla the most corrosive of the sea coast atmospheres.

A summary of the meteorological data for the various locations is given in Table III.

Respectfully submitted on behalf of the subcommittee,

W. H. FINKELDEY,
Chairman.

Changes Due to Atmospheric Corrosion

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material A—Commercial Copper (Tough Pitch)									
Pittsburgh No. 1	+1.44 +1.42	+0.07 −0.07	32 380	42.8	−1.8 *(2.1)*	−1.4 *(3.2)*	−3.0 *(0.7)*	−5.1 *(3.5)*	Fairly uniform, black adherent rough scale.
Altoona No. 2	+0.26 +0.29	−0.93 −1.04	32 550	43.8	−1.3 *(2.1)*	−0.2 *(1.8)*	−2.5 *(0.6)*	−2.9 *(3.5)*	Uniform, brownish-black adherent rough film with red tinge near some edges (iron oxide?)
New York City No. 4	−0.83 −0.83	−2.77 −2.81	32 700	44.2	−1.0 *(2.2)*	+1.4 *(2.1)*	−2.0 *(0.9)*	−2.0 *(3.7)*	Spotty dark green slightly rough adherent film with red-brown areas.
Rochester No. 6	+0.30 +0.28	+1.54 +1.49	32 950	44.7	−0.2 *(2.2)*	+0.9 *(2.2)*	−1.3 *(0.9)*	−0.9 *(6.2)*	Iridescent "peacock" colored rough adherent scale.
Sandy Hook No. 5	+0.49 +0.59	+0.43 +0.56	33 050	44.3	−0.8 *(2.1)*	+1.2 *(2.0)*	−0.7 *(1.0)*	−1.8 *(3.3)*	Olive-green over red-brown, fairly smooth adherent film with spots of patina green.
Key West No. 7	+0.42 +0.43	+0.56 +0.59	33 180	44.8	+0.6 *(2.3)*	+2.1 *(2.5)*	−0.6 *(0.6)*	−0.7 (3.8)	Red-brown smooth adherent film with green patina at some edges.
La Jolla No. 9	+1.54 +1.48	+1.89 +1.78	32 470	43.0	−0.6 *(2.2)*	−0.7 *(2.9)*	−2.7 *(1.4)*	−4.7 *(4.8)*	Red-brown film with overlying blue and green friable scale heaviest at edges.
State College No. 3	+0.33 +0.33	+0.57 +0.56	32 920	44.1	−0.9 *(2.2)*	−3.3 *(11.8)*	−1.4 *(0.9)*	−2.2 *(3.1)*	Dark olive-green adherent smooth film with red-brown areas.
Phoenix No. 8	+0.12 +0.14	+0.10 +0.13	33 150	44.1	+0.3 *(2.4)*	+1.6 *(2.3)*	−0.7 *(1.0)*	−2.2 *(3.1)*	Mottled red-brown smooth adherent film with large green-black area near center.
Material B—Commercial Copper (Phosphorized)									
Pittsburgh No. 1	+1.27 +1.15	−0.09 −0.21	34 700	40.0	−2.5 *(1.3)*	−3.5 *(2.0)*	−3.9 *(1.5)*	−2.4 *(3.7)*	Fairly uniform black adherent rough scale.
Altoona No. 2	+0.06 +0 04	−1.17 −1.16	34 400	41.0	−2.3 *(1.1)*	−3.5 *(2.0)*	−4.8 *(1.7)*	0.0 *(3.1)*	Uniform brownish-black adherent rough film with red tinge near some edges (iron-oxide?).
New York City No. 4	−0.84 −0.85	−2.71 −2.72	34 200	40.0	−2.3 *(1.0)*	−2.3 *(2.9)*	−4.2 *(1.2)*	−2.4 *(3.1)*	Spotty dark green adherent film with red-brown areas.
Rochester No. 6	+0.27 +0.27	+1.40 +1.37	35 100	41.0	−1.4 *(0.8)*	−2.3 *(2.0)*	−1.8 *(1.3)*	0.0 *(1.8)*	Iridescent "peacock" colored rough adherent scale.
Sandy Hook No. 5	+0.51 +0.49	+0.39 +0.36	34 900	42.0	−2.3 *(0.8)*	−1.2 *(2.0)*	−2.2 *(1.2)*	+2.4 *(3.4)*	Olive-green over red-brown fairly smooth adherent film, with spots of patina green.
Key West No. 7	+0.38 +0.38	+0.53 +0.53	35 200	41.5	−0.6 *(0.9)*	−2.3 *(2.0)*	−1.4 *(1.3)*	+1.2 *(2.2)*	Red-brown smooth adherent film with green patina at some edges.
La Jolla No. 9	+1.32 +1.40	+1.58 +1.65	34 600	41.0	−2.0 *(0.8)*	−1.2 *(2.6)*	−3.1 *(1.5)*	0.0 *(2.1)*	Red-brown film with overlying blue-green friable scale heaviest at edges.
State College No. 3	+0.32 +0.32	+0.54 +0.54	35 000	40.5	−1.4 *(1.1)*	−4.7 *(3.1)*	−2.0 *(1.6)*	−1.2 *(1.8)*	Dark olive-green adherent smooth film with red-brown areas.
Phoenix No. 8	+0.11 +0.13	−0.09 +0.10	35 600	41.5	−0.6 *(1.1)*	−3.5 *(2.3)*	−0.3 *(1.4)*	+1.2 *(2.6)*	Mottled red-brown smooth adherent film with large green-black area near center (not so prominent as in material A).

Changes Due to Aging (Storage Specimens)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL A				
Original	35 200	42.4		
After 1 year	34 180	42.9	−2.9 *(2.6)*	+1.2 *(2.1)*
After 3 years	33 380	45.1	−5.2 *(1.7)*	+6.4 *(3.1)*
MATERIAL B				
Original	35 150	38.7		
After 1 year	35 400	43.0	+0.7 *(0.8)*	+11.1 *(1.9)*
After 3 years	35 700	41.0	+1.5 *(1.3)*	+5.1 *(1.9)*

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	After 1 Yr.		After 3 Yr.		
					Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material C—Copper-Silicon-Manganese Alloy (96 Cu, 3 Si, 1 Mn)									
Pittsburgh No. 1.....	+1.42 +1.16	+0.68 +0.47	57 200	58.9	−3.1 (*3.9*)	+1.3 (*5.0*)	−3.0 (*1.6*)	0.0 (*2.7*)	Fairly uniform black adherent rough scale.
Altoona No. 2.....	+0.18 −0.15	−0.63 −1.09	56 920	58.8	−3.8 (*4.2*)	+2.0 (*4.3*)	−3.4 (*1.6*)	−0.2 (*3.8*)	Uniform brown-black adherent rough film with red tinge at some edges (iron-oxide?).
New York City No. 4.....	−0.89 −0.88	−2.63 −2.65	55 530	58.6	−3.5 (*3.8*)	+1.3 (*4.1*)	−5.8 (*4.7*)	−0.4 (*2.9*)	Peacock iridescence on blue-grey areas, adherent slightly rough film.
Rochester No. 6.....	+0.27 +0.26	+1.33 +1.25	59 330	57.7	−0.1 (*5.5*)	−1.4 (*4.7*)	+0.6 (*3.0*)	−2.0 (*4.0*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5.....	+0.47 +0.49	+0.75 +0.78	56 970	59.6	−2.8 (*4.0*)	+2.3 (*4.0*)	−3.4 (*2.0*)	+1.2 (*2.7*)	Olive-green over red-brown adherent smooth film with spots of green patina.
Key West No. 7.....	+0.44 +0.42	+0.84 +0.78	57 820	60.2	−1.7 (*4.2*)	+2.2 (*4.9*)	−1.9 (*1.4*)	+2.2 (*2.7*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9.....	+1.92 +1.77	+3.06 +2.92	56 630	58.9	−1.8 (*5.0*)	+2.0 (*6.2*)	−3.9 (*1.6*)	0.0 (*1.0*)	Red-brown film with overlying blue-green friable scale heaviest at edges.
State College No. 3.....	+0.11 −0.05	+0.16 −0.10	58 680	57.6	+0.8 (*5.3*)	−2.2 (*6.2*)	−0.5 (*1.6*)	−2.2 (*4.0*)	Streaked and mottled yellow-brown adherent smooth film.
Phoenix No. 8.....	+0.12 +0.16	+0.09 +0.10	58 880	59.1	−0.5 (*3.9*)	+0.2 (*4.7*)	−0.1 (*2.1*)	+0.3 (*3.4*)	Yellow-brown adherent smooth tarnish blackened near ends.
Material D—Tin Bronze									
Pittsburgh No. 1.....	+2.23 +2.26	+2.90 +2.51	56 300	64.5	−2.4 (*2.8*)	+3.1 (*1.7*)	−2.6 (*1.6*)	+0.8 (*3.8*)	Fairly uniform black adherent rough scale.
Altoona No. 2.....	+0.79 +0.83	−0.67 −0.57	56 500	65.7	−1.0 (*1.9*)	+1.8 (*3.3*)	−2.2 (*1.5*)	+2.7 (*2.7*)	Uniform brown-black adherent rough film with red tinge at some edges (iron-oxide?).
New York City No. 4.....	−0.22 −0.19	−2.57 −2.08	56 400	65.5	−1.4 (*2.6*)	+0.3 (*2.0*)	−2.4 (*2.5*)	+2.3 (*2.2*)	Slate-gray adherent film with patches of rough black scale.
Rochester No. 6.....	+0.31 +0.30	+1.61 +1.51	57 700	65.7	−0.3 (*2.7*)	+0.8 (*1.9*)	−1.7 (*2.5*)	+2.7 (*2.4*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5.....	+0.63 +0.65	+0.83 +0.86	56 800	67.0	−1.9 (*2.4*)	0.0 (*1.7*)	−1.7 (*1.7*)	+4.7 (*2.5*)	Olive-green over red-brown adherent smooth film with spots of green patina.
Key West No. 7.....	+0.52 +0.53	+0.89 +0.89	58 000	67.3	+0.2 (*1.8*)	+1.1 (*1.4*)	+0.3 (*1.7*)	+5.2 (*2.1*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9.....	+1.83 +1.71	+2.37 +2.13	56 900	66.3	−1.7 (*2.1*)	+1.5 (*2.0*)	−1.6 (*1.8*)	+3.6 (*2.7*)	Red-brown non-adherent scale with non-uniform non-adherent green over-layer.
State College No. 3.....	+0.11 +0.14	+0.25 +0.31	56 800	65.5	+0.9 (*1.9*)	−1.7 (*1.9*)	−1.7 (*2.2*)	+2.3 (*2.7*)	Streaked brown-yellow adherent smooth film.
Phoenix No. 8.....	+0.14 +0.12	+0.11 +0.10	57 300	66.7	+0.7 (*2.2*)	−0.2 (*1.9*)	−0.9 (*2.4*)	+4.2 (*2.9*)	Mottled and streaked orange-brown adherent tarnish.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL C				
Original.......	59 050	55.7		
After 1 year..	59 620	55.5	+1.0 (*3.9*)	−0.4 (*4.2*)
After 3 years..	58 950	58.9	−0.2 (*1.7*)	+5.8 (*3.0*)
MATERIAL D				
Original.......	58 925	66.2		
After 1 year...	58 300	65.3	−1.1 (*2.0*)	−1.4 (*1.4*)
After 3 years..	57 800	64.0	−1.9 (*1.7*)	−3.3 (*2.2*)

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[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material F—Aluminum Bronze (92 Cu, 8 Al)									
Pittsburgh No. 1	+1.57 +1.60	+2.43 +2.28	73 058	49.6	−2.9 (*3.1*)	+4.2 (*5.2*)	−5.9 (*3.3*)	+5.5 (*7.7*)	Fairly uniform black adherent rough scale.
Altoona No. 2	+0.34 +0.47	+0.59 +0.86	73 916	48.3	−2.7 (*2.2*)	+9.8 (*5.8*)	−4.8 (*2.5*)	+2.8 (10.4)	Uniform brown-black adherent rough film with red tinge at some edges (iron oxide?).
New York City No. 4	−0.03 −0.01	−0.55 −0.47	72 908	48.4	−3.3 (*4.0*)	+14.0 (*8.8*)	−6.1 (*3.7*)	+3.0 (*4.0*)	Dark iridescent adherent rough scale.
Rochester No. 6	+0.18 +0.20	+1.44 +1.50	75 675	47.2	+1.9 (*2.7*)	+2.2 (*5.8*)	−2.5 (*3.0*)	+0.4 (*6.0*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5	+0.31 +0.31	+0.59 +0.59	74 533	48.3	−1.0 (*3.1*)	+5.3 (*7.1*)	−4.0 (*2.5*)	+2.8 (*4.2*)	Dirty brown adherent slightly rough scale, green at edges.
Key West No. 7	+0.26 +0.07	+0.39 +0.41	76 050	46.5	+0.2 (*3.6*)	+2.9 (*8.2*)	−2.0 (*3.4*)	−1.1 (*5.3*)	Light red-brown adherent smooth film, green at edges.
La Jolla No. 9	+0.93 +0.95	+0.93 +0.92	85 533	36.6	+0.4 (*2.1*)	−5.8 (*5.6*)	+2.1 (*3.1*)	−3.9 (*5.6*)	Pea green adherent friable scale with yellow under film showing at edges.
State College No. 3	−0.03 −0.03	−0.12 −0.13	75 108	49.7	+1.1 (*3.6*)	+4.9 (*6.5*)	−3.2 (*2.9*)	+5.8 (*4.3*)	Uniform yellow-bronze tarnish.
Phoenix No. 8	+0.09 +0.08	+0.04 +0.04	84 700	38.1	−0.2 (*1.2*)	−2.5 (*6.2*)	+1.1 (*2.1*)	0.0 (*7.3*)	Golden yellow adherent smooth tarnish.
Material G—Commercial Aluminum									
Pittsburgh No. 1	+0.25 +0.23	+0.35 +0.32	16 525	11.2	+0.5 (*1.0*)	−13.4 (*7.4*)	+0.7 (*1.6*)	−18.8 (*8.7*)	Uniform gray adherent slightly rough film with much occluded soot.
Altoona No. 2	+0.31 +0.27	+0.68 +0.53	16 285	11.9	+1.5 (*1.2*)	−12.7 (*10.6*)	−0.7 (*1.7*)	−13.8 (*7.8*)	Uniform dark gray adherent slightly rough film, with much occluded soot.
New York City No. 4	+0.39 +0.36	+0.55 +0.50	16 370	10.4	+1.9 (*1.6*)	−19.7 (*7.0*)	−0.2 (*1.2*)	−24.6 (*8.0*)	Uniform dark gray adherent roughened film, with occluded soot.
Rochester No. 6	+0.09 +0.10	+0.25 +0.26	16 350	12.2	+2.4 (*2.4*)	−7.7 (*6.3*)	−0.3 (*1.0*)	−11.6 (*7.0*)	Uniform light gray adherent film, considerably roughened in vertical central area of specimen.
Sandy Hook No. 5	+0.28 +0.26	+0.59 +0.50	16 500	10.9	+3.9 (*1.9*)	−16.2 (*8.7*)	+0.6 (*0.9*)	−21.0 (*9.1*)	Light gray adherent film, with numerous white specks from non-uniform corrosion.
Key West No. 7	+0.09 +0.14	+0.32 +0.25	16 590	12.1	+2.8 (*4.2*)	−9.9 (*11.2*)	+1.1 (*1.7*)	−12.3 (*7.2*)	Light gray film, with fine white specks from non-uniform attack.
La Jolla No. 9	+0.76 +0.76	+1.42 +1.40	15 360	3.8	−2.2 (*1.4*)	−69.9 (*7.0*)	−6.4 (*3.4*)	−72.5 (*8.5*)	Light gray film speckled with white scale; non-uniform attack.
State College No. 3	0.00 +0.01	−0.01 0.00	16 555	12.5	+3.4 (*2.2*)	−4.9 (*13.1*)	+0.9 (*2.6*)	−9.4 (*8.7*)	Uniform tarnish, with a small spotted pattern.
Phoenix No. 8	+0.04 +0.04	+0.01 +0.01	16 695	13.7	+3.5 (*3.0*)	−11.2 (*11.0*)	+1.8 (*3.5*)	−0.7 (*13.7*)	Tarnish with light spots of thin film.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL F				
Original[b]	(1)74 070 (2)82 858	46.6 39.9		
After 1 year	(1)75 825 (2)83 320	45.0 39.5	+2.4 (*2.3*) +0.4 (*1.4*)	−3.5 (4.8) −1.0 (*5.4*)
After 3 years	(1)77 625 (2)83 750	47.0 38.1	+4.1 (*2.2*) +1.1 (*2.4*)	+0.9 (*3.6*) −4.5 (*5.6*)
MATERIAL G				
Original	16 410	14.6		
After 1 year	16 215	14.2	−1.2 (*1.5*)	−2.7 (*20.5*)
After 3 years	16 405	13.8	0.0 (*2.4*)	−5.5 (*22.0*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

[b] Two lots of material F, necessitating tests of two storage sets:
(1) Values for use with results from stations No. 1 to No. 7, inclusive.
(2) Values for use with results from stations No. 8 and No. 9.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material I—Al-Mn Alloy (1 per cent Mn)									
Pittsburgh No. 1	+0.21 +0.21	+0.09 +0.09	19 730	8.3	−3.0 (*1.6*)	−17.0 (*9.6*)	−3.7 (*0.7*)	−8.8 (*17.1*)	Uniform gray adherent film, slightly roughened, with much occluded soot.
Altoona No. 2	+0.25 +0.23	+0.26 +0.02	19 530	8.0	−3.4 (*1.6*)	−17.0 (*11.7*)	−4.7 (*0.9*)	−12.1 (*14.8*)	Uniform dark gray adherent film, slightly roughened, with much occluded soot.
New York City No. 4	+0.22 +0.24	+0.21 +0.21	19 605	7.3	−2.2 (*1.5*)	−31.0 (*8.1*)	−4.3 (*0.8*)	−19.8 (*14.5*)	Uniform dark gray adherent roughened film, with occluded soot.
Rochester No. 6	+0.13 +0.14	+0.25 +0.26	20 370	9.1	−0.8 (*1.8*)	−7.0 (*7.8*)	−0.6 (*0.9*)	0.0 (*13.9*)	Light gray adherent film, speckled with black scale in some areas, plate specimens mechanically damaged.
Sandy Hook No. 5	+0.16 +0.24	+0.25 +0.37	20 050	9.0	−2.0 (*1.4*)	−9.0 (*12.0*)	−2.1 (*1.2*)	−1.1 (*22.4*)	Light gray adherent film, speckled by a non-uniform attack.
Key West No. 7	+0.08 +0.09	+0.15 +0.20	20 300	9.3	−0.7 (*1.7*)	−4.0 (*8.1*)	−0.9 (*1.2*)	+2.2 (*15.2*)	Light gray film, speckled by a non-uniform attack.
La Jolla No. 9	+0.58 +0.56	+0.85 +0.78	19 070	3.6	−1.5 (*1.8*)	−42.0 (*14.1*)	−6.9 (*2.6*)	−60.4 (*13.5*)	Light gray film heavily speckled by a non-uniform attack.
State College No. 3	+0.10 0.0	+0.08 −0.01	20 235	9.3	−0.5 (*1.8*)	−7.0 (*8.1*)	−1.3 (*1.0*)	+2.2 (*14.5*)	Tarnish, showing a spotted pattern.
Phoenix No. 8	+0.03 +0.03	+0.01 +0.01	20 640	9.3	−0.1 (*1.7*)	+2.0 (*13.2*)	+0.7 (*1.5*)	+2.2 (*17.5*)	Bright surface with some spots and streaks of light film.
Material K—Manganese Bronze									
Pittsburgh No. 1	+1.24 +1.29	+2.59 +2.64	115 156	5.6	−2.9 (*4.3*)	−4.0 (*37.7*)	−13.0 (*7.6*)	−16.4 (*36.3*)	Uniform blue-black adherent rough scale.
Altoona No. 2	+1.16 +1.09	+2.47 +2.31	109 414	5.4	−8.4 (*5.6*)	+12.0 (*49.9*)	−17.3 (*8.2*)	−19.4 (*31.3*)	Uniform black adherent rough scale.
New York City No. 4	+1.14 +1.12	+1.97 +1.95	104 881	5.0	−3.9 (*6.6*)	−27.0 (*43.8*)	−20.8 (*7.8*)	−25.4 (*30.5*)	Uniform black adherent rough scale, stippled with gray spots.
Rochester No. 6	+0.46 +0.43	+1.88 +1.75	138 849	5.9	−0.8 (*7.1*)	−25.6 (*35.3*)	+4.9 (*7.6*)	−11.9 (*31.3*)	Uniform black adherent rough scale with iridescent streaks.
Sandy Hook No. 5	+0.85 +0.73	+1.68 +1.40	123 183	5.8	+9.7 (*14.1*)	−25.6 (*33.2*)	−6.9 (*8.5*)	−13.4 (*30.9*)	Uniform blue-black adherent rough scale.
Key West No. 7	+0.56 +0.56	+1.74 +1.68	122 942	5.2	+2.7 (*6.8*)	−17.6 (*40.1*)	−7.1 (*7.3*)	−22.4 (*29.1*)	Uniform dark brown adherent rough scale, stippled with black spots.
La Jolla No. 9	+1.50 +1.65	+2.50 +2.85	95 338	2.4	−19.0 (*11.2*)	−66.2 (*32.8*)	−28.0 (*9.4*)	−64.2 (*30.5*)	Black adherent rough scale with numerous small dezincified spots.
State College No. 3	−0.05 −0.02	−0.17 −0.11	125 312	5.8	+2.4 (*6.8*)	−21.6 (*36.9*)	−5.3 (*8.1*)	−13.4 (*35.8*)	Uniform brown adherent smooth film with scattered black spots.
Phoenix No. 8	+0.09 +0.10	+0.07 +0.07	120 530	5.9	+2.5 (*7.6*)	−17.6 (*33.7*)	−8.9 (*9.4*)	−11.9 (*30.5*)	Uniform brown adherent smooth tarnish with scattered black spots.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL I				
Original	20 450	9.4		
After 1 year	20 505	10.0	+0.3 (*4.9*)	+6.4 (*38.3*)
After 3 years	20 490	9.1	+0.2 (*3.9*)	−3.2 (*45.0*)
MATERIAL K				
Original	122 999	8.5		
After 1 year	121 705	7.4	−1.1 (*1.5*)	−13.0 (*37.7*)
After 3 years	132 372	6.7	+7.6 (*2.5*)	−21.2 (*34.8*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material L—Brass (85 Cu, 15 Zn)									
Pittsburgh No. 1	+1.36 +1.21	+1.18 +1.19	39 030	40.6	−3.2 (*2.4*)	−1.3 (*3.1*)	−4.8 (*2.6*)	+3.0 (*4.7*)	Fairly uniform black adherent rough scale.
Altoona No. 2	+0.78 +0.72	+0.54 +0.46	39 690	41.1	−1.7 (*1.6*)	+0.8 (*3.1*)	−3.2 (*2.1*)	+1.2 (*4.8*)	Uniform brown-black adherent rough film with red tinge at some edges (iron-oxide?).
New York City No. 4	−0.07 −0.12	−1.79 −1.72	39 740	40.9	−0.5 (*1.7*)	−0.5 (*3.6*)	−3.0 (*1.6*)	+3.8 (*3.8*)	Blue-black adherent rough scale with slate-gray streaks.
Rochester No. 6	+0.24 +0.27	+1.38 +1.20	40 416	40.9	−0.2 (*1.8*)	+0.3 (*3.1*)	−1.2 (*1.4*)	+3.8 (*3.0*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5	+0.37 +0.37	+0.24 +0.23	39 900	40.9	−1.8 (*1.5*)	+1.3 (*3.2*)	−2.6 (*1.6*)	+3.8 (*3.1*)	Olive-green over red-brown adherent smooth film with spots of green patina.
Key West No. 7	+0.24 +0.22	+0.27 +0.25	40 970	40.1	−0.6 (*1.1*)	−0.5 (*3.1*)	0.0 (*1.8*)	+1.8 (*2.9*)	Red-brown adherent smooth film with green patina at some edges.
La Jolla No. 9	+1.15 +1.08	+1.39 +1.31	40 210	41.6	−1.6 (*1.3*)	+1.8 (*5.6*)	−1.9 (*1.2*)	+5.6 (*2.5*)	Red-brown film with blue-green adherent scale, heaviest at edges (green at edges only, not so pronounced as material A at location No. 9).
State College No. 3	+0.01 +0.01	−0.12 −0.01	40 580	40.2	−0.8 (*1.9*)	+0.5 (*4.1*)	−1.0 (*1.6*)	+2.0 (*2.3*)	Yellow-brown adherent film.
Phoenix No. 8	+0.10 +0.10	+0.07 +0.07	41 708	40.3	+0.2 (*1.8*)	+0.5 (*3.2*)	+1.8 (*1.5*)	+2.3 (*3.1*)	Mottled yellow-brown adherent smooth film.
Material M—Brass (70–30)									
Pittsburgh No. 1	−0.45 −0.47	−1.86 −2.71	44 000	56.0	−3.3 (*0.9*)	0.0 (*5.8*)	−10.0 (*1.7*)	−3.4 (*4.6*)	Dark iridescent adherent rough scale.
Altoona No. 2	−0.53 −0.50	−2.27 −2.33	44 700	54.0	−2.3 (*1.9*)	+2.6 (*6.3*)	−8.6 (*2.2*)	−6.9 (*5.0*)	Dark iridescent adherent rough scale.
New York City No. 4	−1.42 −1.47	−4.15 −4.29	43 000	51.0	−5.4 (*1.1*)	−3.5 (*6.0*)	−12.0 (*2.1*)	−12.0 (*7.0*)	Dark iridescent adherent scale.
Rochester No. 6	+0.20 +0.19	+0.52 +0.49	47 700	57.0	−0.4 (*0.7*)	+5.3 (*7.1*)	−2.5 (*1.8*)	−1.7 (*6.3*)	Dark iridescent adherent rough scale.
Sandy Hook No. 5	+0.21 +0.23	−0.06 −0.10	47 000	56.5	−2.3 (*1.1*)	−0.9 (*7.2*)	−3.9 (*2.1*)	−2.6 (*7.0*)	Green-gray adherent rough scale.
Key West No. 7	−0.14 +0.16	−0.25 +0.06	48 300	57.0	+0.4 (*1.7*)	+4.4 (*5.1*)	−1.2 (*1.8*)	−1.7 (*8.2*)	Dusty green-gray adherent outer film over red-brown adherent smooth film.
La Jolla No. 9	+0.82 +0.89	+0.85 +0.88	46 700	57.0	−3.9 (*2.4*)	+4.4 (*4.8*)	−4.1 (*1.8*)	−1.7 (*5.2*)	Salmon-pink film with overlying green adherent scale, indications of incipient dezincification.
State College No. 3	−0.05 −0.06	−0.23 −0.24	49 100	58.5	−0.6 (*1.7*)	+2.6 (*6.7*)	+0.4 (*1.8*)	+0.9 (*6.3*)	Brown-black adherent smooth film.
Phoenix No. 8	+0.12 +0.10	+0.07 +0.06	48 600	59.0	+1.0 (*0.8*)	+7.0 (*5.5*)	−0.6 (*1.9*)	+1.7 (*6.9*)	Green-yellow adherent tarnish with scattered iridescence.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL L				
Original	39 896	40.7		
After 1 year	40 750	39.7	+2.1 (*1.4*)	−2.5 (*3.2*)
After 3 years	40 980	39.4	+2.7 (*1.6*)	−3.2 (*2.7*)
MATERIAL M				
Original	48 033	52.3		
After 1 year	48 500	57.0	+1.0 (*0.9*)	+9.0 (*5.5*)
After 3 years	48 900	58.0	+1.8 (*1.8*)	+10.9 (*5.0*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material N—Admiralty Metal									
Pittsburgh No. 1.....	+0.69 +0.74	+0.60 −0.28	52 300	52.2	−1.3 (*1.4*)	+4.4 (*2.2*)	−3.5 (*0.8*)	+3.4 (*1.5*)	Fairly uniform black adherent rough scale.
Altoona No. 2.....	−0.50 −0.53	−1.45 −1.45	52 800	52.0	−0.9 (*1.2*)	+2.6 (*1.5*)	−2.6 (*1.0*)	+3.0 (*1.2*)	Uniform brown-black adherent rough film with red tinge at some edges (iron oxide?).
New York City No. 4.....	−1.25 −1.26	−3.39 −3.44	52 500	51.8	−0.6 (*1.0*)	+4.6 (*1.5*)	−3.1 (*0.8*)	+2.6 (*1.5*)	Spotty dark green adherent rough film with red-brown areas.
Rochester No. 6.....	+0.15 +0.19	+0.71 +0.81	53 400	51.8	0.0 (*1.4*)	+4.6 (*1.5*)	−1.5 (*1.2*)	+2.6 (*1.5*)	Iridescent "peacock colored" adherent smooth film.
Sandy Hook No. 5.....	+0.26 +0.24	+0.03 −0.01	53 100	51.8	+0.2 (*1.1*)	+3.4 (*1.5*)	−2.0 (*1.0*)	+2.6 (*1.5*)	Green-gray adherent slightly rough scale.
Key West No. 7.....	+0.21 +0.22	+0.16 +0.17	53 500	51.7	−0.2 (*1.2*)	+2.6 (*1.5*)	−1.3 (*0.9*)	+2.4 (*1.7*)	Dusty green-gray adherent outer film over red-brown adherent smooth film.
La Jolla No. 9.....	+0.92 +0.94	+1.26 +1.32	53 400	52.3	−0.6 (*1.2*)	+5.0 (*1.2*)	−[illegible].5 (*0.7*)	+3.6 (*1.7*)	Red-brown adherent film with overlying green film, green at edges.
State College No. 3.....	−0.07 −0.07	−0.27 −0.26	53 700	51.5	+0.6 (*1.1*)	+3.6 (*2.2*)	−0.9 (*1.2*)	+2.0 (*2.2*)	Yellow-brown adherent smooth film streaked with black.
Phoenix No. 8.....	+0.09 +0.09	+0.04 +0.04	54 200	51.0	−0.4 (*1.2*)	+1.4 (*2.1*)	0.0 (*1.1*)	+1.0 (*1.2*)	Green-yellow adherent smooth tarnish with scattered iridescence.
Material O—Duralumin (4 Cu, 0.5 Mn, 0.5 Mg)									
Pittsburgh No. 1.....	+0.73 +0.84	+0.87 +0.96	60 870	14.8	−3.9 (*1.6*)	−22.6 (*5.2*)	−6.6 (*1.6*)	−32.6 (*7.0*)	Uniform gray adherent slightly rough film with much occluded soot.
Altoona No. 2.....	+0.68 +0.66	+0.96 +0.94	59 755	13.1	−10.0 (*7.1*)	−45.4 (*17.7*)	−8.3 (*1.5*)	−40.5 (*4.9*)	Uniform dark gray adherent slightly rough film, with much occluded soot.
New York City No. 4.....	+0.87 +1.04	+1.00 +1.15	59 790	11.4	−8.5 (*3.8*)	−46.3 (*12.5*)	−8.3 (*1.9*)	−48.2 (*6.6*)	Uniform dark gray adherent rough film, with occluded soot.
Rochester No. 6.....	+0.42 +0.49	+1.33 +1.39	62 860	16.3	−2.9 (*2.6*)	−23.2 (*13.6*)	−3.5 (*1.0*)	−25.9 (*5.7*)	Uniform gray adherent roughened film with fine light gray scale specks.
Sandy Hook No. 5.....	+1.05 +1.09	+1.41 +1.40	59 445	12.3	−9.5 (*4.1*)	−44.5 (*14.2*)	−8.8 (*7.8*)	−39.5 (*13.9*)	Uniform light gray adherent film with spots of white scale.
Key West No. 7.....	+0.87 +0.64	+1.17 +0.91	62 925	15.5	−4.1 (*3.1*)	−37.2 (*14.5*)	−3.5 (*2.0*)	−29.3 (*5.5*)	Light gray film speckled with numerous white specks; non-uniform attack.
La Jolla No. 9.....	+2.89 +2.84	+3.48 +3.42	43 440	2.8	−34.5 (*4.9*)	−91.7 (*11.2*)	−33.3 (*4.0*)	−87.2 (*5.1*)	Gray film speckled with numerous white specks; non-uniform attack.
State College No. 3.....	−0.01 −0.01	−0.03 −0.03	63 875	20.5	+0.7 (*2.3*)	−7.2 (*7.4*)	−2.0 (*2.3*)	−6.8 (*7.1*)	Tarnished.
Phoenix No. 8.....	+0.06 +0.10	+0.03 +0.07	65 385	21.1	−0.7 (*1.9*)	−5.8 (*6.1*)	+0.3 (*1.4*)	−4.1 (*6.1*)	Non-uniform light gray adherent film, slightly roughened.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL N				
Original.......	54 958	51.1		
After 1 year...	53 900	50.5	−1.9 (*0.8*)	−1.2 (*1.8*)
After 3 years..	54 200	50.5	−1.4 (*0.8*)	−1.2 (*1.8*)
MATERIAL O				
Original.......	63 760	20.7		
After 1 year...	65 430	20.7	+2.6 (*4.6*)	0.0 (*18.8*)
After 3 years..	65 170	22.0	+2.2 (*3.4*)	+6.3 (*18.5*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	After 1 Yr.		After 3 Yr.		
					Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)									
Pittsburgh No. 1	+0.25 +0.23	−2.89 −2.52	50 970	32.1	−3.4 (*1.8*)	+0.3 (*1.6*)	−3.2 (*2.5*)	0.0 (*3.8*)	Brown-black adherent rough brittle scale.
Altoona No. 2	−0.43 −0.43	−3.52 −3.12	50 180	31.7	−1.4 (*1.5*)	0.0 (*2.1*)	−4.7 (*1.5*)	−1.2 (*3.2*)	Brown-black adherent rough brittle scale.
New York City No. 4	−1.29 −1.34	−3.95 −4.03	50 820	31.8	−2.6 (*1.8*)	−0.3 (*1.3*)	−3.5 (*1.6*)	−0.9 (*2.9*)	Green-gray patina film with black iridescent spots one side; other side, green-gray with blue-black iridescent spots.
Rochester No. 6	+0.20 +0.19	+0.71 +0.67	52 600	32.1	−0.5 (*1.4*)	+0.3 (*1.3*)	−0.2 (*1.1*)	0.0 (*2.6*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5	+0.09 +0.10	−0.95 −1.27	51 650	32.0	−1.7 (*1.3*)	+0.9 (*1.9*)	−2.0 (*1.0*)	−0.3 (*3.3*)	Green-gray adherent scale with brown areas near edges.
Key West No. 7	+0.08 +0.08	−0.01 −0.02	52 580	31.8	−2.1 (*1.9*)	+0.3 (*2.3*)	−0.2 (*1.3*)	−0.9 (*3.0*)	Uniform red-tan adherent smooth film.
La Jolla No. 9	+0.50 +0.46	+0.35 +0.30	52 550	32.1	−0.9 (*1.6*)	−0.3 (*2.3*)	−0.2 (*1.9*)	0.0 (*3.3*)	Light green smooth thin scale over tan adherent film.
State College No. 3	−0.06 −0.07	−0.26 −0.27	52 320	31.8	−1.0 (*1.4*)	+0.9 (*1.6*)	−0.7 (*1.2*)	−0.9 (*3.7*)	Uniform dark brown adherent smooth film.
Phoenix No. 8	+0.09 +0.11	+0.08 +0.08	52 400	32.1	−0.7 (*1.2*)	+0.6 (*1.3*)	−0.5 (*1.2*)	0.0 (*3.1*)	Olive-green adherent tarnish.
Material Q—Cu-Ni-Sn Alloy									
Pittsburgh No. 1	0.00 −0.05	−2.77 −2.35	78 500	20.7	+2.0 (*11.5*)	−7.5 (*28.0*)	+1.8 (*9.9*)	−14.8 (*27.2*)	Brown-black adherent rough brittle scale
Altoona No. 2	−0.74 −0.69	−2.66 −2.65	79 600	20.0	+6.7 (*11.6*)	−17 5 (*25.2*)	+3.2 (*10.4*)	−17.7 (*27.9*)	Brown-black adherent rough brittle scale
New York City No. 4	−1.34 −1.35	−4.40 −4.41	74 000	24.8	+2.4 (*8.8*)	−5.6 (*23.4*)	−4.0 (*7.8*)	+2.1 (*23.1*)	Green-gray patina film, black iridescent spots one side—other side same, blue-black iridescent spots. (Color not so prominent as material P at location No. 4).
Rochester No. 6	+0.13 +0.17	+0.78 +0.77	77 500	22.3	+3.2 (*6.7*)	−9.5 (*15.8*)	+0.5 (*6.4*)	−8.2 (*19.1*)	Iridescent "peacock" colored adherent rough scale.
Sandy Hook No. 5	+0.10 +0.10	−0.80 −0.79	74 600	25.0	+4.0 (*11.3*)	−9.9 (*26.9*)	−3.2 (*5.5*)	+2.9 (*14.8*)	Green-gray adherent smooth scale with brown areas near edges.
Key West No. 7	+0.05 +0.07	−0.01 −0.01	74 900	25.2	−1.2 (*5.7*)	+7.1 (*13.8*)	−2.9 (*6.4*)	+3.7 (*18.4*)	Red-tan adherent smooth film with overlying green film.
La Jolla No. 9	+0.31 +0.33	+0.17 +0.14	78 500	22.3	+2.4 (*7.2*)	−8.7 (*18.7*)	+1.8 (*9.8*)	−8.2 (*27.5*)	Thin light green smooth scale over tan adherent film.
State College No. 3	−0.11 −0.11	−0.31 −0.31	76 300	24.7	+3.0 (*10.1*)	−7.9 (*26.5*)	−1.0 (*10.0*)	+1.6 (*25.2*)	Light olive-green adherent smooth tarnish.
Phoenix No. 8	+0.08 +0.08	+0.05 +0.05	79 300	21.2	+0.9 (*8.0*)	−2.0 (*20.2*)	+2.9 (*8.5*)	−12.8 (*19.8*)	Olive-green adherent tarnish.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL P				
Original	54 350	31.5		
After 1 year	54 000	31.8	−0.6 (*1.2*)	+0.9 (*3.2*)
After 3 years	52 680	32.1	−3.1 (*1.1*)	+1.9 (*2.9*)
MATERIAL Q				
Original	76 792	24.2		
After 1 year	75 800	25.2	−1.3 (*6.8*)	+4.0 (*23.6*)
After 3 years	77 100	24.3	+0.4 (*5.7*)	+0.4 (*25.0*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italicfigures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 Yr.		After 3 Yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
					Material S—Nickel-Copper Alloy (70 Ni, 30 Cu)				
Pittsburgh No. 1	−1.14 −1.12	−3.00 −2.94	79 200	35.3	+1.4 (*1.4*)	+0.3 (*1.8*)	+0.1 (*1.8*)	−1.1 (*1.2*)	Gray-brown smooth film, black on lower edge.
Altoona No. 2	−1.10 −1.09	−3.88 −3.88	78 850	34.8	+0.6 (*2.4*)	−1.1 (*4.9*)	−0.4 (*1.1*)	−2.5 (*1.6*)	Shaded brown-black slightly rough adherent film, red tinge near some edges.
New York City No. 4	−1.61 −1.65	−4.42 −4.45	77 000	36.3	−1.0 (*2.0*)	+2.0 (*2.2*)	−2.7 (*1.8*)	+1.7 (*1.5*)	Brown-black smooth film.
Rochester No. 6	−0.16 −0.17	−0.59 −0.60	79 500	36.0	+0.8 (*1.8*)	−0.3 (*2.2*)	+0.4 (*1.7*)	+0.8 (*0.9*)	Non-uniform iridescent dark smooth film.
Sandy Hook No. 5	−0.44 −0.41	−1.87 −1.73	79 250	35.9	+1.5 (*1.9*)	0.0 (*1.7*)	+0.1 (*1.3*)	+0.6 (*1.1*)	Uniform green-gray smooth film, heavier on bottom edge.
Key West No. 7	−0.10 −0.08	−0.24 −0.23	80 000	35.8	+0.8 (*1.5*)	−0.6 (*2.2*)	+1.1 (*1.2*)	+0.3 (*1.8*)	Initial cold-rolled surface with green-gray tarnish.
La Jolla No. 9	+0.15 +0.19	−0.25 −0.23	80 000	34.9	+1.0 (*1.3*)	−1.1 (*1.8*)	+1.1 (*1.3*)	−2.2 (*2.6*)	Green-gray film with spots of light scale of corrosion product.
State College No. 3	−0.15 −0.16	−0.37 −0.39	79 000	35.5	−0.3 (*1.3*)	+1.1 (*1.8*)	−1.9 (*1.0*)	−0.6 (*1.3*)	Initial cold-rolled surface, very slightly tarnished.
Phoenix No. 8	+0.02 +0.02	−0.05 −0.05	78 500	35.7	+1.9 (*1.7*)	0.0 (*2.2*)	−0.8 (*0.9*)	0.0 (*1.2*)	Initial cold-rolled surface, slightly tarnished.
					Material T—Commercial Nickel				
Pittsburgh No. 1	−3.90 −3.86	−10.82 −10.71	69 500	36.5	−1.5 (*1.8*)	−1.1 (*1.7*)	−5.2 (*3.2*)	+0.6 (*1.6*)	Uniform green-brown smooth film.
Altoona No. 2	−3.83 −3.95	−11.76 −12.04	69 200	37.0	−1.7 (*1.8*)	+0.8 (*1.4*)	−5.3 (*1.2*)	+1.9 (*2.3*)	Mottled green-black slightly rough film.
New York City No. 4	−5.01 −5.07	−12.48 −12.58	70 450	35.8	−2.1 (*2.2*)	−1.1 (*1.4*)	−3.6 (*1.7*)	−1.4 (*1.5*)	Mottled green-gray tarnish.
Rochester No. 6	−0.53 −0.54	−2.03 −2.06	72 100	35.9	−0.2 (*2.0*)	−1.4 (*1.8*)	−1.3 (*0.9*)	−1.1 (*2.0*)	Mottled gray-black smooth film.
Sandy Hook No. 5	−0.74 −0.74	−2.36 −2.39	72 250	36.5	−0.2 (*1.7*)	−2.4 (*1.0*)	−1.1 (*0.7*)	+0.6 (*1.6*)	Slightly mottled gray tarnish.
Key West No. 7	−0.14 −0.14	−0.41 −0.41	72 500	36.3	−1.2 (*2.0*)	−0.8 (*1.3*)	−0.8 (*1.3*)	0.0 (*2.1*)	Initial cold-rolled surface slightly tarnished.
La Jolla No. 9	+0.08 +0.10	−0.19 −0.19	72 500	36.0	−0.3 (*2.2*)	−0.8 (*1.6*)	−0.8 (*1.0*)	−0.8 (*1.3*)	Initial cold-rolled surface with numerous small speckles.
State College No. 3	−0.12 −0.12	−0.39 −0.38	72 550	36.1	−0.8 (*2.2*)	0.0 (*1.7*)	−0.7 (*1.3*)	−0.6 (*1.2*)	Slight tarnish (initial cold-rolled surface).
Phoenix No. 8	0.00 0.00	−0.06 −0.06	73 000	35.7	−0.9 (*1.8*)	−3.3 (*1.0*)	−0.1 (*0.8*)	−1.7 (*1.2*)	Initial cold-rolled surface very slightly tarnished.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
		MATERIAL S		
Original	79 835	35.7		
After 1 year	77 900	35.6	−2.4 (*1.8*)	−0.3 (*2.2*)
After 3 years	79 150	35.7	−0.9 (*1.7*)	0.0 (*1.8*)
		MATERIAL T		
Original	71 040	35.8		
After 1 year	72 050	36.8	+1.4 (*1.8*)	+2.8 (*1.8*)
After 3 years	73 080	36.3	+2.9 (*0.4*)	+1.3 (*1.8*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 yr.		After 3 yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
				Material U—Chemical Lead					
Pittsburgh No. 1	+0.14 +0.03	−0.21 −0.24	2 335	41.6	+2.3 (*1.9*)	−8.9 (*8.4*)	−0.9 (*1.3*)	+5.6 (*8.8*)	Dark gray film with some white streaking.
Altoona No. 2	−0.21 −0.24	−0.66 −0.76	2 323	40.7	+3.5 (*1.8*)	−8.0 (*7.1*)	−1.4 (*1.3*)	+3.3 (*8.9*)	Almost black film with white lines where sheet was mechanically deformed; red tinge near some edges.
New York City No. 4	−0.04 −0.11	−0.47 −0.89	2 332	39.2	+2.3 (*1.9*)	−2.6 (*7.8*)	−1.0 (*1.5*)	−0.5 (*14.2*)	Tarnish (⅕) and gray film (⅘) varying from dark to white, mostly dark.
Rochester No. 6	+0.04 0.0	0.0 −0.03	2 396	42.9	+6.4 (*3.2*)	−2.8 (*9.1*)	+1.7 (*1.1*)	+8.9 (*10.5*)	Dark gray film with some white spots (water drop), small amount tarnish.
Sandy Hook No. 5	−0.13 −0.17	−1.19 −1.11	2 342	40.8	+2.1 (*2.4*)	−0.9 (*8.0*)	−0.6 (*1.1*)	+3.6 (*14.7*)	Light gray tarnish with white filmed spot (water drop).
Key West No. 7	−0.50 −0.45	−1.19 −1.24	2 357	41.1	+4.9 (*2.1*)	−8.9 (*7.0*)	0.0 (*1.0*)	+4.3 (*16.3*)	Gray film one side, whitish gray on other.
La Jolla No. 9	+0.29 +0.33	+0.10 −0.14	2 356	39.4	+1.0 (*1.7*)	−9.2 (*7.7*)	0.0 (*1.3*)	0.0 (*10.3*)	General gray film, with overlying white chalky scale spots covering micro-pits, some areas slightly green.
State College No. 3	+0.02 −0.10	−0.50 −0.64	2 345	38.6	+3.9 (*2.1*)	−5.9 (*9.6*)	−0.5 (*1.0*)	−2.0 (*11.0*)	Tarnish (½) and gray film (½) with white streaks and specks, micro-pits under white specks.
Phoenix No. 8	−0.04 −0.03	−0.17 −0.20	2 350	42.6	+7.0 (*2.2*)	+2.3 (*13.3*)	−0.3 (*1.4*)	+8.1 (*8.6*)	Mostly dark tarnish, some white film where mechanically deformed, white spots covering micro-pits on one specimen.
				Material Z—Al-Mg-Si Alloy (98 Al, 0.5 Mg, 1 Si)					
Pittsburgh No. 1	+0.22 +0.21	+0.27 +0.28	38 820	18.8	−2.6 (*1.3*)	−21.6 (*10.1*)	−5.7 (*1.5*)	−23.0 (*11.2*)	Uniform gray adherent film, with much occluded soot.
Altoona No. 2	+0.25 +0.22	+0.56 +0.47	38 050	16.1	−5.6 (*6.6*)	−22.5 (*8.8*)	−7.6 (*1.6*)	−34.0 (*7.0*)	Uniform dark gray adherent film, slightly roughened, with much occluded soot.
New York City No. 4	+0.32 +0.33	+0.41 +0.39	37 915	14.8	−5.5 (*2.7*)	−38.9 (*11.1*)	−7.9 (*2.6*)	−39.3 (*10.3*)	Uniform dark gray adherent roughened film, with occluded soot.
Rochester No. 6	+0.11 +0.09	+0.21 +0.20	40 780	18.9	−0.9 (*1.4*)	−12.0 (*7.8*)	−0.9 (*2.7*)	−22.5 (*8.5*)	Light gray spotted adherent film, with some roughening in wide center streak.
Sandy Hook No. 5	+0.22 +0.21	+0.33 +0.27	39 275	16.3	−3.3 (*1.3*)	−27.7 (*8.1*)	−4.6 (*1.9*)	−33.2 (*6.2*)	Light gray adherent film (slightly speckled) from a non-uniform attack.
Key West No. 7	+0.13 +0.09	+0.16 +0.14	40 640	16.6	−1.1 (*1.2*)	−29.7 (*8.8*)	−1.3 (*1.1*)	−31.9 (*7.6*)	Light gray film, speckled with white spots from a non-uniform attack.
La Jolla No. 9	+0.78 +0.85	+0.96 +1.00	31 375	4.9	−20.4 (*4.3*)	−76.7 (*7.2*)	−23.8 (*5.1*)	−79.8 (*7.6*)	Light gray film (heavily speckled) with white scale spots from a non-uniform attack.
State College No. 3	−0.01 −0.01	−0.03 −0.02	40 050	22.3	−0.6 (*0.8*)	−9.2 (*11.6*)	−2.7 (*1.4*)	−8.6 (*8.5*)	Tarnish with light spotted film.
Phoenix No. 8	+0.02 +0.03	0.00 +0.01	43 005	21.7	+1.8 (*0.9*)	−15.2 (*8.9*)	+4.5 (*3.5*)	−11.1 (*7.4*)	Tarnish, with some very lightly speckled filmed areas.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
		MATERIAL U		
Original	2 582	43.6		
After 1 year	2 338	42.7	−9.5 (*2.6*)	−2.1 (*7.8*)
After 3 years	2 356	39.4	−9.1 (*2.3*)	−9.6 (*8.3*)
		MATERIAL Z		
Original	39 975	23.9		
After 1 year	40 455	24.9	+6.5 (*4.5*)	+4.2 (*17.4*)
After 3 years	41 160	24.4	+8.4 (*5.2*)	+2.1 (*17.4*)

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[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 yr.		After 3 yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material AA—Commercial Zinc (Prime Western Grade)									
Pittsburgh No. 1	−2.21 −2.30	−6.41 −6.62	27 600	30.0	−5.7 (*1.7*)	−10.8 (*14.6*)	−6.4 (*2.6*)	−13.3 (*10.3*)	Uniform light gray adherent thin film (sooty).
Altoona No. 2	−2.67 −2.73	−8.49 −8.63	27 200	31.3	−3.0 (*1.7*)	−12.4 (*17.6*)	−7.8 (*1.5*)	−9.5 (*12.4*)	Uniform dark gray adherent thin film (sooty) with red tinge near some edges.
New York City No. 4	−3.27 −3.23	−9.61 −9.48	27 400	29.8	−3.7 (*1.3*)	−18.3 (*14.1*)	−7.1 (*2.0*)	−16.8 (*18.3*)	Uniform gray adherent thin film.
Rochester No. 6	−0.20 −0.24	−0.97 −1.12	28 800	26.8	0.0 (*1.4*)	−16.5 (*14.9*)	−2.4 (*2.3*)	−22.5 (*10.2*)	Uniform light gray adherent thin film, streaked with soot and dirt.
Sandy Hook No. 5	−0.45 −0.45	−2.31 −2.38	28 300	33.3	−1.7 (*1.2*)	−13.6 (*15.1*)	−4.0 (*1.6*)	−3.8 (*14.7*)	Uniform light gray adherent thin film.
Key West No. 7	+0.20 +0.31	+0.04 +0.06	29 300	33.0	+0.3 (*1.2*)	−7.2 (*17.3*)	−0.7 (*2.5*)	−4.6 (*7.9*)	Uniform light gray adherent thin film with white friable scale along edges.
La Jolla No. 9	+2.68 +3.10	+4.88 +5.21	27 200	13.0	−10.0 (*2.9*)	−69.3 (*18.6*)	−7.8 (*1.6*)	−62.4 (*10.3*)	Uniform heavy white friable scale, bulky on edges.
State College No. 3	−0.06 −0.11	−1.05 −1.07	28 600	32.1	−2.0 (*1.2*)	−10.3 (*15.9*)	−3.1 (*1.7*)	−7.2 (*14.9*)	Uniform light gray adherent thin film.
Phoenix No. 8	+0.11 +0.12	+0.04 +0.04	29 300	35.4	+1.4 (*1.0*)	−11.8 (*17.5*)	−0.7 (*1.8*)	+2.3 (*13.5*)	Distinctly tarnished.
Material BB—Commercial Zinc (High Grade)									
Pittsburgh No. 1	−2.35 −2.34	−6.93 −7.02	17 600	54.9	−2.7 (*0.9*)	−1.8 (*7.0*)	−3.8 (*1.1*)	−5.8 (*3.5*)	Uniform light gray adherent thin film (sooty).
Altoona No. 2	−2.84 −2.80	−8.86 −8.90	17 600	51.0	−2.1 (*0.7*)	−6.7 (*4.3*)	−3.8 (*1.0*)	−12.5 (*3.7*)	Uniform dark gray adherent thin film (sooty with red tinge near some edges).
New York City No. 4	−3.65 −3.60	−10.49 −10.40	17 400	54.0	−2.1 (*0.5*)	−1.4 (*4.4*)	−4.9 (*1.1*)	−6.9 (*3.5*)	Uniform gray adherent thin film.
Rochester No. 6	−0.26 −0.26	−1.31 −1.31	18 100	53.6	−0.5 (*0.7*)	−0.9 (*7.7*)	−1.1 (*1.1*)	−8.1 (*4.6*)	Uniform light gray adherent thin film, streaked with soot and dirt.
Sandy Hook No. 5	−0.49 −0.59	−2.58 −2.84	18 100	54.0	−1.1 (*0.7*)	+2.8 (*7.9*)	−1.1 (*0.9*)	−6.9 (*4.9*)	Uniform light gray adherent thin film.
Key West No. 7	+0.13 +0.13	−0.19 −0.19	18 300	58.5	+0.5 (*0.8*)	+0.9 (*5.7*)	0.0 (*1.2*)	+0.3 (*4.3*)	Uniform light gray adherent thin film with white friable scale along edges.
La Jolla No. 9	+2.98 +3.10	+4.89 +4.69	17 200	37.5	−4.3 (*0.7*)	−10.8 (*9.6*)	−6.0 (*1.2*)	−35.6 (*4.8*)	Uniform heavy white friable scale, bulky on edges.
State College No. 3	−0.27 −0.27	−1.30 −1.28	17 900	58.6	−1.3 (*0.9*)	0.0 (*4.2*)	−2.2 (*2.0*)	+0.5 (*4.4*)	Uniform light gray adherent thin film.
Phoenix No. 8	+0.08 +0.08	0.0 0.0	18 400	55.9	+0.5 (*0.7*)	−0.7 (*6.9*)	+0.5 (*1.1*)	−4.1 (*6.2*)	Distinctly tarnished with areas of light gray adherent water-spotted film.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL AA				
Original	29 900	34.3		
After 1 year	29 600	38.8	−1.0 (*1.2*)	+13.1 (*16.3*)
After 3 years	29 500	34.6	−1.3 (*1.5*)	+0.9 (*9.6*)
MATERIAL BB				
Original	18 280	58.5		
After 1 year	18 600	56.3	+1.8 (*0.8*)	−3.8 (*6.2*)
After 3 years	18 300	58.3	+0.1 (*1.1*)	−0.3 (*5.6*)

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[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 yr.		After 3 yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material CC—Lead Antimony Alloy (1 per cent Sb)									
Pittsburgh No. 1	0.0 +0.04	−0.21 −0.14	3 223	43.7	+4.3 (*3.4*)	−8.6 (*12.0*)	−0.3 (*1.7*)	−7.4 (*11.6*)	Tarnish (½), black film (½), white near edge.
Altoona No. 2	−0.15 −0.16	−0.56 −0.41	3 152	43.5	+1.8 (*1.9*)	−5.4 (*7.5*)	−2.5 (*1.2*)	−7.8 (*6.0*)	Dark gray film, white near supports; red tinge near some edges.
New York City No. 4	−0.02 0.0	−0.26 −0.24	3 187	44.2	+0.7 (*2.5*)	−5.4 (*3.7*)	−1.4 (*1.1*)	−6.4 (*6.5*)	Dark gray tarnish.
Rochester No. 6	+0.03 +0.02	+0.08 +0.06	3 165	45.2	+1.6 (*2.8*)	−0.4 (*4.7*)	−2.1 (*1.2*)	−4.2 (*7.5*)	Dark iridescent tarnish, with white film spots (water drops).
Sandy Hook No. 5	−0.04 −0.16	−0.56 −0.54	3 125	44.6	+0.5 (*1.6*)	−6.9 (*4.5*)	−3.3 (*1.0*)	−5.5 (*6.5*)	Gray tarnish, with some patches of gray and white film.
Key West No. 7	−0.33 −0.34	−0.66 −0.89	3 110	43.6	+2.8 (*3.3*)	−6.2 (*3.4*)	−3.8 (*1.4*)	−7.6 (*6.0*)	Tarnish (⅓), light gray film (⅔).
La Jolla No. 9	+1.37 +0.77	+1.17 +0.74	3 157	43.1	+0.2 (*1.7*)	−9.7 (*11.8*)	−2.3 (*1.0*)	−8.7 (*7.3*)	Light gray chalky film, 20 per cent area green film.
State College No. 3	−0.21 −0.20	−0.53 −0.59	3 160	45.6	+3.0 (*4.7*)	−2.6 (*4.9*)	−2.2 (*1.5*)	−3.4 (*6.9*)	Gray tarnish.
Phoenix No. 8	−0.05 −0.03	−0.18 −0.17	3 073	45.2	+1.9 (*1.9*)	−4.3 (*2.8*)	−4.8 (0.9)	−4.2 (*6.5*)	Tarnish (½) and gray film (½).
Material EE—Commercial Tin									
Pittsburgh No. 1	+0.33 +0.32	+0.39 +0.66	3 222	62.7	−1.5 (*6.5*)	+2.6 (*27.7*)	−1.1 (*4.8*)	−7.4 (*15.5*)	General gray film with white and black specks, micro-pits beneath white.
Altoona No. 2	+0.45 +0.46	+1.27 +1.27	3 040	58.4	+4.1 (*5.9*)	+0.7 (*30.8*)	−6.7 (*3.6*)	−13.7 (*19.7*)	Dark (½) and light (½) gray film, with white specks; red tinge near some edges.
New York City No. 4	+0.50 +0.52	+0.89 +0.92	3 112	67.6	+0.9 (*5.8*)	−6.8 (*27.2*)	−4.5 (*3.9*)	−0.2 (*17.2*)	Gray film with white specks.
Rochester No. 6	+0.33 +0.32	+0.53 +0.55	3 168	64.1	+1.8 (*4.8*)	−0.7 (*30.6*)	−2.8 (*4.6*)	−5.3 (*17.8*)	Gray film with white specks.
Sandy Hook No. 5	+1.04 +1.00	+1.24 +1.19	3 045	44.5	+1.5 (*6.1*)	−21.3 (*26.5*)	−6.5 (*5.0*)	−34.3 (*16.2*)	Light gray film with white veins and specks of corrosion deposit.
Key West No. 7	+0.43 +0.47	+1.12 +1.17	3 081	63.9	+4.1 (*5.8*)	−6.3 (*30.7*)	−5.4 (*5.2*)	−5.6 (*17.2*)	Gray film with large white specks.
La Jolla No. 9	+1.50 +1.45	+2.40 +2.16	2 888	26.1	−3.5 (*4.4*)	−54.0 (*27.7*)	−11.4 (*8.9*)	−61.6 (*14.7*)	White film with heavier white deposit in spots, some yellow spots.
State College No. 3	+0.19 +0.17	+0.22 +0.21	3 158	61.7	+4.1 (*6.0*)	+2.2 (*27.5*)	−3.1 (*3.7*)	−8.9 (*15.2*)	White speckled light gray film.
Phoenix No. 8	+0.14 +0.14	+0.19 +0.20	3 085	64.6	−0.9 (*5.6*)	−7.5 (*32.9*)	−5.3 (*4.6*)	−4.6 (*17.4*)	Generally bright with white specks.

CHANGES DUE TO AGING (STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL CC				
Original	3 482	45.3		
After 1 year	3 214	46.3	−7.7 (*1.9*)	+2.2 (*3.5*)
After 3 years	3 232	47.2	−7.2 (*1.7*)	+4.2 (*5.8*)
MATERIAL EE				
Original	3 760	60.3		
After 1 year	3 390	58.7	−9.8 (*4.6*)	−2.6 (*27.3*)
After 3 years	3 258	67.7	−13.4 (*3.9*)	+11.7 (*17.7*)

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

CHANGES DUE TO ATMOSPHERIC CORROSION

Location	Actual Change in Weight, g.		Tensile Properties After 3 Yr. Exposure		Percentage Change in Tensile Properties (Italic figures in parentheses indicate maximum percentage difference due to chance.)				Remarks
					After 1 yr.		After 3 yr.		
	After 1 yr.	After 3 yr.	Tensile Strength, lb. per sq. in.	Elongation, per cent	Tensile Strength[a]	Percentage Elongation[a]	Tensile Strength[a]	Percentage Elongation[a]	
Material FF—Aluminum Coated Duralumin									
Pittsburgh No. 1	+0.20 +0.18	+0.18 +0.14	58 490	19.6	−1.1 *(1.9)*	−6.1 *(5.7)*	−1.4 *(2.3)*	+1.0 *(6.0)*	Uniform gray adherent film, slightly roughened, with much occluded soot.
Altoona No. 2	+0.27 +0.24	+0.37 +0.39	57 910	18.2	−0.7 *(1.5)*	−1.5 *(7.7)*	−2.3 *(2.3)*	−6.2 *(10.2)*	Uniform dark gray adherent film, slightly roughened, with much occluded soot.
New York City No. 4	+0.35 +0.32	+0.26 +0.24	58 745	19.7	−0.4 *(2.0)*	−1.5 *(6.0)*	−0.9 *(2.6)*	+1.6 *(5.1)*	Uniform dark gray adherent roughened film, with occluded soot.
Rochester No. 6	+0.12 +0.11	+0.29 +0.22	58 620	18.3	−0.9 *(2.2)*	−5.6 *(8.1)*	−1.1 *(2.0)*	−5.7 *(10.4)*	Speckled gray film, considerably roughened in wide vertical streak in center.
Sandy Hook No. 5	+0.20 +0.23	+0.25 +0.26	57 380	18.3	−0.3 *(1.7)*	−4.1 *(6.9)*	−3.2 *(2.9)*	−5.7 *(5.0)*	Light gray adherent film, speckled by a non-uniform attack.
Key West No. 7	+0.09 +0.07	+0.14 +0.12	58 395	17.1	+1.2 *(1.5)*	−5.1 *(6.7)*	−1.5 *(2.4)*	−11.8 *(17.3)*	Light gray film, with white speckles from a non-uniform attack.
La Jolla No. 9	+0.62 +0.63	+0.55 +0.60	58 720	19.6	0.0 *(2.6)*	−4.1 *(6.1)*	−1.0 *(2.3)*	+1.0 *(7.1)*	Light gray film, with numerous white specks from a non-uniform attack.
State College No. 3	−0.01 +0.09	−0.03 +0.07	59 140	18.8	−1.5 *(2.6)*	−8.2 *(10.0)*	−0.3 *(2.5)*	−3.1 *(14.2)*	Tarnish mottled with slight film.
Phoenix No. 8	+0.03 +0.03	+0.01 +0.01	58 695	18.7	+0.1 *(2.1)*	−7.1 *(9.0)*	−1.0 *(2.8)*	−3.6 *(15.3)*	Spotted tarnish and light film.
Material HH—Commercial Zinc (High Grade 99.99+ per cent Zn)									
Pittsburgh No. 1	−2.52 −3.29	−7.59 −7.98	17 350	52.2	−2.7 *(2.0)*	−0.7 *(6.3)*	−6.0 *(1.9)*	−0.9 *(2.5)*	Uniform light gray adherent thin film (sooty).
Altoona No. 2	−2.92 −2.83	−9.15 −9.03	17 350	48.3	−5.9 *(1.7)*	−6.3 *(3.6)*	−6.0 *(1.3)*	−13.3 *(5.9)*	Uniform dark gray adherent thin film (sooty with red tinge near some edges).
New York City No. 4	−3.68 −3.66	−10.81 −10.77	17 550	48.8	−3.2 *(1.6)*	−3.7 *(6.6)*	−4.9 *(1.5)*	−12.4 *(5.8)*	Uniform gray adherent thin film.
Rochester No. 6	−0.22 −0.22	−1.25 −1.24	18 350	50.0	−0.8 *(1.4)*	−5.3 *(7.4)*	−0.5 *(1.0)*	−10.2 *(7.2)*	Uniform dark gray adherent thin film.
Sandy Hook No. 5	−0.44 −0.46	−2.57 −2.60	18 300	53.1	−1.3 *(1.2)*	+0.5 *(7.7)*	−0.8 *(1.2)*	−4.7 *(5.1)*	Uniform light gray adherent thin film.
Key West No. 7	+0.14 +0.22	−0.18 −0.08	18 450	52.3	0.0 *(1.5)*	−7.3 *(7.5)*	0.0 *(1.7)*	−6.1 *(4.9)*	Uniform gray adherent thin film with traces of white corrosion.
La Jolla No. 9	+2.53 +2.40	+3.96 +3.75	17 100	34.8	−4.0 *(1.8)*	−14.5 *(8.3)*	−7.3 *(1.3)*	−37.6 *(6.6)*	Non-uniform heavy white friable scale (darker in center than material AA at location No. 9).
State College No. 3	−0.13 −0.07	−1.32 −1.28	18 350	53.5	−1.9 *(1.8)*	−5.9 *(4.0)*	−0.5 *(1.1)*	−3.9 *(7.3)*	Uniform gray adherent thin film.
Phoenix No. 8	+0.09 +0.09	0.0 −0.01	18 750	53.3	+0.5 *(1.1)*	−2.9 *(7.1)*	+1.6 *(1.4)*	−4.3 *(5.1)*	Distinctly tarnished with areas of light gray adherent water-spotted film.

CHANGES DUE TO AGING
(STORAGE SPECIMENS)

	Tensile Strength, lb. per sq. in.	Elongation, per cent	Percentage Change[a]	
			Tensile Strength	Percentage Elongation
MATERIAL FF				
Original	58 790	19.5		
After 1 year	59 535	19.6	+1.3 *(4.2)*	+0.5 *(17.5)*
After 3 years	59 300	19.4	+8.7 *(5.8)*	−0.5 *(16.2)*
MATERIAL HH				
Original	18 800	51.6		
After 1 year	18 600	55.9	−1.1 *(1.3)*	+8.3 *(6.1)*
After 3 years	18 450	55.7	−1.9 *(1.2)*	+7.9 *(4.2)*

[a] Italic figures in parentheses indicate maximum percentage difference due to chance.

REPORT OF SUBCOMMITTEE VII ON CORROSION IN LIQUIDS

The work of Subcommittee VII as outlined in last year's report,[1] has been continued. The work of the four sections of this committee are reported upon below.

Section 1 on Corrosion in Sodium Chloride Solutions (W. R. Webster, chairman):

The rack of test samples as described in the 1934 report of Subcommittee VII[1] was placed in a circulating water suction well at a power station at Bridgeport, Conn., on May 5, 1934. It was removed January 3, 1935, after an exposure period of 243 days to salt harbor water. When removed from the well the rack and samples were covered with a large amount of seaweed and marine life and growth. This was washed off with a hose and the rack allowed to dry out.

Samples of the water taken from the well showed a chlorine content of 16 parts per thousand. The following is a record of the temperature of the water over the months the samples were immersed:

May, 1934	47 – 49 F.
June, 1934	59 – 68 F.
July, 1934	66 – 73 F.
August, 1934	69 – 74 F.
September, 1934	69 – 72 F.
October, 1934	53 – 70 F.
November, 1934	48 – 55 F.
December, 1934	37 – 50 F.

A visual inspection of the dried out rack by various members of the committee resulted in the following description of the kind and nature of corrosion product and the condition of the samples:

Material	
A	Dull brownish green scale; edge corrosion.
B	Dull brownish green scale; edge corrosion.
C	Dull brownish green scale; edge corrosion, greater edge corrosion in tension test section.
D	Dull red scale with green patches.
E	Dull greenish brown scale.
F	Dull yellow brown scale.
H	Dull brown scale with white encrustations. After cleaning corrosion was apparent under these encrustations. Specimen H-8 had broad shallow pits green in the bottoms.
J	White encrustations; dull steel color.
K	Dark brown with yellow brown encrustations. One specimen broke at holes and was lost; remaining two samples almost completely dezincified on testing.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 222 (1934).

L	Dull brownish green scale. Specimen L-6 and L-8 show edge corrosion, specimen L-9 shows slight edge corrosion.
M	Dull brownish green scale. Specimen M-6 and M-8 show edge corrosion.
N	Dull brownish green; very slight edge corrosion.
P	Dull brownish green.
Q	Dull brownish green. Specimen Q-6 shows edge corrosion on shank.
R	Dull brownish green; edge corrosion.
S	Brown scale; numerous small shallow pits.
T	Dark gray; scattered irregular shallow pits; ends pitted. Specimen T-9 had oval perforation at one end; broke at this perforation when tested.
V	One specimen gone; broke at the holes. One specimen steel gray, one specimen dull steel gray with large areas of rust. Decided action and perforation, particularly at contacts with wood rack; white encrustations.
W	Lustrous steel color. Small shallow pits on specimen W-86 and very slight pits on specimen W-85, none on specimen W-84. White encrustations.
Y	Heavy brownish green scale.

The corrosion product was removed with hydrochloric acid. The test data and summary of results are given in Table I.

New racks are being built for further tests of this nature in which series of tests lead will be included.

In addition to the work reported above, a test rack was removed from a salt grainer for examination. It was found that practically all specimens were uncorroded due to a deposit of protective salts. The specimens were therefore cleaned and put back for further exposure.

Section 2 on Corrosion in Sodium Hydroxide (W. G. Whitman, chairman):

Section 2 is testing the metals A, D, H, J, L, M, N, P, Q, R, S, T and W against sodium hydroxide solutions as they occur in evaporators employed for the commercial production of electrolytic caustic soda and for the recovery of alkali from the black liquor of a soda pulp mill.[1]

The section has completed weight loss determinations and tension tests on 117 corroded specimens. The corroded specimens were exposed in three racks. During the exposures designated A-11[1] and B-12[1] some of the glass insulators failed. The results of these runs are, therefore, of uncertain value. After the rack was redesigned, exposure A-11 was made. The glass insulators came through intact and the results of the run are considered satisfactory. Data obtained from these tests appear in Table II. The values given represent the average of the results obtained on three separate specimens, except where otherwise noted.

The three racks of specimens were prepared according to the procedure and design previously described. Two racks were placed at test locations Nos. 11 and 12. Placement of the third rack was delayed until the evaporator was opened, which ordinarily occurs every six months.

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[1] For details see *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 225 (1934).

TABLE I.—RESULTS OF SEA WATER CORROSION TEST.
May 5, 1934 to January 3, 1935.

Specimen	Loss in Weight, g.	Corrosion, mg. per sq. dm. per day	Tensile Strength, lb. per sq. in.	Loss in Tensile Strength, lb. per sq. in.	Percentage Loss in Tensile Strength	Elongation, per cent	Loss in Elongation, per cent	Percentage Loss in Elongation
MATERIAL A—COMMERCIAL COPPER (TOUGH PITCH)								
Unexposed Average	......	......	34 283	......	......	43.2	......	......
No. 50	2.8428	......	30 300	......	......	37.5	......	......
No. 49	2.8625	......	30 100	......	......	24.5	......	......
No. 48	3.1920	......	30 400	......	......	37.5	......	......
Average	2.9991	12.2	30 266	4 017	11.7	33.2	10.0	23.1
MATERIAL B—COMMERCIAL COPPER (PHOSPHORIZED)								
Unexposed Average	......	......	36 050	......	......	42.0	......	......
No. 39	2.9536	......	30 200	......	......	32.0	......	......
No. 38	4.3698	......	31 800	......	......	33.5	......	......
No. 37	3.5440	......	30 600	......	......	27.5	......	......
Average	3.6224	14.7	30 866	5 184	14.4	31.0	11.0	26.2
MATERIAL C—CU-SI-MN ALLOY (96 CU, 3 SI, 1 MN)								
Unexposed Average	......	......	59 366	......	......	56.8	......	......
No. 9	2.6035	......	49 500	......	......	39.0	......	......
No. 8	2.9517	......	50 200	......	......	30.0	......	......
No. 7	3.1849	......	51 000	......	......	46.5	......	......
Average	2.9133	11.8	50 233	9 133	15.4	38.5	18.3	32.2
MATERIAL D—TIN BRONZE (92 CU, 8 SN)								
Unexposed Average	......	......	58 433	......	......	66.2	......	......
No. 9	1.3242	......	55 700	......	......	69.0	......	......
No. 8	1.5578	......	54 400	......	......	61.0	......	......
No. 7	1.9386	......	53 100	......	......	66.5	......	......
Average	1.6068	6.5	54 400	4 033	6.9	65.5	0.7	1.1
MATERIAL E—ALUMINUM BRONZE (95 CU, 5 AL)								
Unexposed Average	......	......	68 333	......	......	42.7	......	......
No. 6	2.0581	......	68 500	......	......	28.0	......	......
No. 7	2.0361	......	66 000	......	......	36.0	......	......
No. 8	1.9848	......	59 400	......	......	48.0	......	......
Average	2.0263	8.2	64 633	3 700	5.4	37.3	5.4	12.6
MATERIAL F—ALUMINUM BRONZE (92 CU, 8 AL)								
Unexposed Average	......	......	82 566	......	......	39.8	......	......
No. 9	0.4255	......	81 500	......	......	41.0	......	......
No. 8	0.5323	......	78 700	......	......	42.0	......	......
No. 7	0.6564	......	78 700	......	......	38.0	......	......
Average	0.5381	2.8	79 633	2 933	3.6	40.3	0	0
MATERIAL H—ALUMINUM BRONZE (89 CU, 10 AL, 1 FE)								
Unexposed Average	......	......	90 200	......	......	19.2	......	......
No. 4	1.0208	......	67 300	......	......	5.0	......	......
No. 9	1.1517	......	58 300	......	......	4.5	......	......
No. 8	2.1685	......	62 700	......	......	6.0	......	......
Average	1.4470	5.9	62 766	27 434	30.3	5.2	14.0	72.9
MATERIAL J—LOW-CARBON NI-CR-FE (22 NI, 20 CR, BAL. FE)								
Unexposed Average	......	......	85 266	......	......	38.7	......	......
No. 189	0.0220	0.09	84 500	......	......	30.5	......	......
No. 188	0.0220	0.09	84 900	......	......	27.5	......	......
No. 187	0.0128	0.05	82 600	......	......	30.0	......	......
Average	0.0189	0.08	84 000	1 266	1.5	29.3	9.4	24.3
MATERIAL K—MANGANESE BRONZE (65 CU, 23 ZN, 6 AL, 4 MN, 2 FE)								
Unexposed Average	......	......	127 466	......	......	8.7	......	......
No. 9	5.1323	......	51 500	......	......	0.0	......	......
No. 7	Specimen dropped off rack—Lost							
No. 8	5.0115	......	48 500	......	......	5.0	......	......
Average	5.0719	20.5	50 000	77 466	60.8	0.25	8.4	97.1
MATERIAL L—BRASS (85 CU, 15 ZN)								
Unexposed Average	......	......	41 483	......	......	38.8	......	......
No. 9	4.0100	......	36 400	......	......	33.0	......	......
No. 6	3.3731	......	35 200	......	......	35.0	......	......
No. 8	3.9086	......	34 600	......	......	24.0	......	......
Average	3.7639	15.2	35 400	6 083	14.7	30.7	8.1	20.9

TABLE I. *Continued.*

Specimen	Loss in Weight, g.	Corrosion, mg. per sq. dm. per day	Tensile Strength, lb. per sq. in.	Loss in Tensile Strength, lb. per sq. in.	Percentage Loss in Tensile Strength	Elongation, per cent	Loss in Elongation, per cent	Percentage Loss in Elongation
Material M—Brass (70 Cu, 30 Zn)								
Unexposed Average	......	......	49 883	......	......	52.0	......	......
No. 9	2.8532	......	42 800	......	......	39.0	......	......
No. 6	3.3630	......	43 500	......	......	49.5	......	......
No. 8	3.7777	......	40 500	......	......	39.5	......	......
Average	3.3313	13.5	42 266	7 617	15.3	42.7	9.3	17.9
Material N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)								
Unexposed Average	......	......	54 633	......	......	49.2	......	......
No. 9	2.5831	......	47 500	......	......	51.0	......	......
No. 8	3.0064	......	45 900	......	......	48.0	......	......
No. 7	3.2493	......	50 300	......	......	46.5	......	......
Average	2.9462	11.9	47 900	6 733	12.3	48.5	0.7	1.4
Material P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)								
Unexposed Average	......	......	53 566	......	......	32.5	......	......
No. 9	1.9647	......	49 200	......	......	28.0	......	......
No. 8	2.1098	......	48 600	......	......	25.0	......	......
No. 7	2.2911	......	48 600	......	......	28.5	......	......
Average	2.1218	8.6	48 800	4 766	8.9	27.2	5.3	16.3
Material Q—Cu-Ni-Sn Alloy (70 Cu, 29 Ni, 1 Sn)								
Unexposed Average	......	......	79 566	......	......	22.2	......	......
No. 9	1.2436	......	85 800	......	......	14.0	......	......
No. 4	1.3634	......	72 600	......	......	13.0	......	......
No. 6	1.4849	......	74 300	......	......	21.0	......	......
Average	1.3639	5.5	77 566	2 000	2.5	16.0	6.2	27.9
Material R—Cupro Nickel (83 Cu, 17 Ni)								
Unexposed Average	......	......	51 800	......	......	30.5	......	......
No. 9	2.2036	......	44 200	......	......	16.5	......	......
No. 7	2.2183	......	47 700	......	......	22.5	......	......
No. 6	2.1331	......	47 300	......	......	29.5	......	......
Average	2.1849	8.8	46 400	5 400	10.4	22.8	7.7	25.2
Material S—Nickel-Copper Alloy (70 Ni, 30 Cu)								
Unexposed Average	......	......	80 233	......	......	35.8	......	......
No. 9	1.5574	......	75 000	......	......	24.0	......	......
No. 8	1.2346	......	77 000	......	......	32.5	......	......
No. 7	1.6300	......	76 700	......	......	27.0	......	......
Average	1.4740	6.0	76 233	4 000	5.0	27.8	8.0	22.3
Material T—Commercial Nickel (99+ per cent Pure)								
Unexposed Average	......	......	73 933	......	......	35.5	......	......
No. 8	1.2198	......	73 600	......	......	34.5	......	......
No. 7	1.0727	......	72 300	......	......	27.5	......	......
No. 9	1.3787	......	70 400	......	......	19.5	......	......
Average	1.2241	5.0	72 100	1 833	2.5	27.2	8.3	23.4
Material V—Fe-Cr Alloy								
Unexposed Average	......	......	68 300	......	......	21.0	......	......
No. 34	7.5787	31.0	65 700	......	......	8.0	......	......
No. 35	Lost from rack							
No. 36	6.7518	27.6	48 400	......	......	8.0	......	......
Average	7.1652	29.3	57 050	11 250	16.9	8.0	13.0	61.9
Material W—Fe-Cr-Ni Alloy (18 Cr, 8 Ni, bal. Fe)								
Unexposed Average	......	......	100 200	......	......	55.2	......	......
No. 86	0.3867	1.6	102 200	......	......	27.0	......	......
No. 85	0.0644	0.3	86 100	......	......	26.0	......	......
No. 84	0.1798	0.7	94 700	......	......	45.0	......	......
Average	0.2103	0.9	94 333	5 867	5.9	32.7	22.5	40.6
Material Y—Leaded Bronze (75 Cu, 10 Sn, 15 Pb)								
Unexposed Average	......	......	32 066	......	......	14.0	......	......
No. 1A	8.31	19.4	32 900	......	......	14.0	......	......
No. 1B	9.17	21.5	31 200	......	......	12.5	......	......
No. 1C	11.09	26.0	34 800	......	......	18.0	......	......
Average	9.52	22.3	32 966	0	0	14.8	0	0

Before the third rack was placed, examination of the test rack at test location No. 11 showed that some of the glass insulators had failed, making intermetallic contact between the frame and some specimens a possibility.

TABLE II.—RESULTS OF CORROSION TESTS IN SODIUM HYDROXIDE.

Material	Change in Weight, g.	Average Breaking Strength, lb.	Average Elongation in 2 in., per cent	Change in Elongation[b]	Corrosion Rate, mg. per sq. dm. per day	Percentage Change	
						Breaking Strength	Elongation
TEST LOCATION NO. 11—EXPOSED 52 DAYS[c]							
A—Commercial Copper (Tough Pitch)	−6.4	27 300	40	−3	118.	−18.8	−7.0
D—Tin Bronze (92 Cu, 8 Sn)	−6.4	46 900	63	−5	119.	−20.1	−7.4
H—Aluminum Bronze	−6.2	66 400	22	+1	115.	−27.0	+4.8
J—Low-Carbon Ni-Cr-Fe (22 Ni, 20 Cr, bal. Fe)	−0.12	85 600	41	+9	2.2	+2.1	+28.
L—Brass (85 Cu, 15 Zn)	−5.8	34 600	42	+1	107.	−15.8	+2.4
M—Brass (70 Cu, 30 Zn)	−5.7	41 500	55	+2	105.	−15.8	+3.8
N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)	−6.2	44 200	51	+3	114.	−18.3	+6.3
P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)	−1.1	53 600	30	−2	19.8	−0.2	−6.3
Q—Cu-Ni-Sn Alloy (70 Cu, 29 Ni, 1 Sn)	−0.23	80 500	21	−3	4.2	+4.5	−12.5
R—Cupro-Nickel (83 Cu, 17 Ni)	−1.7	49 900	28	−3	31.8	−3.7	−9.7
S—Nickel-Copper Alloy (70 Ni, 30 Cu)	−0.048	80 200	36	0	0.9	+2.4	0
T—Commercial Nickel (99+ per cent Pure)	−0.016	73 200	36	0	0.3	−0.7	0
W—Fe-Cr-Ni Alloy (18 Cr, 8 Ni, bal. Fe)	−0.051	96 300	52	0	0.9	−2.6	0
TEST LOCATION NO. 11 (REPEAT TESTS)—EXPOSED 56 DAYS							
A—Commercial Copper (Tough Pitch)	−7.2	26 500	41	−2	123.	−21.1	−4.7
D—Tin Bronze (92 Cu, 8 Sn)	−7.5	42 700	63	−5	129.	−27.2	−7.4
H—Aluminum Bronze	−6.8	70 000	21	0	117.	−23.0	0
J—Low-Carbon Ni-Cr-Fe (22 Ni, 20 Cr, bal. Fe)	−0.16	83 800	41	+9	2.7	0	+28.0
L—Brass (85 Cu, 15 Zn)	−7.3	31 700	41	0	126.	−22.9	0
M—Brass (70 Cu, 30 Zn)	−8.0	36 500	54	+1	143.	−26.0	+1.9
N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)	−7.5	41 100	50	+2	129.	−24.0	+4.2
P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)	−1.2	52 100	31	−1	21.	−3.0	−3.1
Q—Cu-Ni-Sn Alloy (70 Cu, 29 Ni, 1 Sn)	−0.27	81 200	21	−3	4.6	+5.5	−12.5
R—Cupro-Nickel (83 Cu, 17 Ni)	−1.8	49 000	31	0	31.	−4.5	0
S—Nickel-Copper Alloy (70 Ni, 30 Cu)	−0.064	81 000	36	0	1.1	+3.4	0
T—Commercial Nickel (99+ per cent Pure)	−0.031	73 300	36	0	0.5	−0.5	0
W—Fe-Cr-Ni Alloy (18 Cr, 8 Ni, bal. Fe)	−0.039	96 900	48	−4	0.6	−2.0	−7.7
TEST LOCATION NO. 12—EXPOSED 111 DAYS[c]							
A—Commercial Copper (Tough Pitch)	[a]	......	..	....	......	......	......
D—Tin Bronze (92 Cu, 8 Sn)	[a]	......	..	....	......	......	......
H—Aluminum Bronze	−20.7	12 300	2	−19	180	−86.5	−91
J—Low-Carbon Ni-Cr-Fe Alloy (22 Ni, 20 Cr, bal. Fe)	−0.079	85 100	41	+9	0.68	+1.5	+28
L—Brass (85 Cu, 15 Zn)	[a]	......	..	....	......	......	......
M—Brass (70 Cu, 30 Zn)	[a]	......	..	....	......	......	......
N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)	[a]	......	..	....	......	......	......
P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)	−9.4	42 600	30	−2	81	−20.7	−6.3
Q—Cu-Ni-Sn Alloy (70 Cu, 29 Ni, 1 Sn)	−5.5	69 700	19	−5	48	−9.5	−20.8
R—Cupro-Nickel (83 Cu, 17 Ni)	−7.8	42 900	27	−4	67	−16.4	−12.9
S—Nickel-Copper Alloy (70 Ni, 30 Cu)	−0.80	82 500	36	0	7.0	+5.4	0
T—Commercial Nickel (99+ per cent Pure)	−0.38	73 400	36	0	3.3	−0.4	0
W—Fe-Cr-Ni Alloy (18 Cr, 8 Ni, bal. Fe)	−0.001	95 800	50	−2	0.008	−3.1	−3.9

[a] Specimens were either lost or so badly disintegrated that values were not obtainable.

[b] This is the change from the original elongation. It is not a percentage change of the percentage elongation in 2 in.

[c] Glass insulators failed in these tests.

The specimens of the third rack were then transferred to a re-designed rack, the main feature of which was a slot support at one end of the specimens to avoid stress on the glass insulators. The re-designed rack was not placed at test location No 13, as previously stated, but was placed at test location No. 11 where the evaporator is usually opened bi-weekly. At the end of the exposure no failure of the glass had occurred.

The corroded samples were cleaned by rubbing lightly with steel wool in water. They were then rinsed in alcohol, dried, weighed and subjected to tensile test. The section is indebted to Prof. R. G. Adams of the Massachusetts Institute of Technology for the breaking load and elongation determinations.

In the practical application of the results of these tests, consideration should be given to two important matters. First, contact of dissimilar metals when wetted with caustic solution may lead to localized attack and unsatisfactory service from metal which otherwise is resistant under the above test conditions. Second, the above conditions of test include the element of stress only in so far as residual stress occurs within the specimens. Steel tubes frequently fail by cracking at the tube sheet rather than by general corrosion.

Table III.—Results of Corrosion Tests in Sulfuric Acid.

Material	Series D Test Location No. 31, 42 days exposure		Series C Test Location No. 32, 59 days exposure		Series C Test Location No. 33, 92 days exposure	
	Loss in Weight, g.	Corrosion Rate, mg. per sq. dm. per day	Loss in Weight, g.	Corrosion Rate, mg. per sq. dm. per day	Loss in Weight, g.	Corrosion Rate, mg. per sq. dm. per day
A—Commercial Copper	19.9	451	17.8	286	31.0	320
C—Cu-Si-Mn Alloy (96 Cu, 3 Si, 1 Mn)	18.0	408	15.6	251	26.3	272
D—Tin Bronze (92 Cu, 8 Sn)	23.0	521	17.6	284	32.0	330
H—Aluminum Bronze	15.6	354	14.9[a]	248	23.1	238
J—Low-Carbon Ni-Cr-Fe-Alloy (22 Ni, 20 Cr, bal. Fe)	0.2	5	3.2	52	2.4	24
K—Manganese Bronze	17.9	406	[b]	...	[c]	...
L—Brass (85 Cu, 15 Zn)	19.2	435	18.5	298	28.3	292
M—Brass (70 Cu, 30 Zn)	19.2	435	[b]	...	[c]	...
N—Admiralty Metal (70 Cu, 29 Zn, 1 Sn)	18.2	413	[b]	...	28.5	294
P—Cu-Ni-Zn Alloy (75 Cu, 20 Ni, 5 Zn)	18.8	427	18.6	299	28.0	289
Q—Cu-Ni-Sn Alloy (70 Cu, 29 Ni, 1 Sn)	18.3	415	18.1	291	26.6	274
R—Cupro-Nickel (83 Cu, 17 Ni)	19.3	437	19.2	308	29.4	303
S—Nickel-Copper Alloy (70 Ni, 30 Cu)	14.5	329	20.3	326	25.2	260
T—Commercial Nickel (99+ per cent)	14.4	327	27.4	441	[c]	...
X—Silicon Cast Iron	3.5	46	8.4	79	0.4	2
Y—Leaded Bronze (75 Cu, 10 Sn, 15 Pb)	25.6	337	33.9	320	43.6	263

[a] Two specimens lost due to brittleness.
[b] All specimens lost due to brittleness.
[c] All specimens lost.

From the three sets of tests completed it is possible to divide the specimens roughly into three groups: the first group of very severely corroded specimens contains materials A, D, H, L, M and N; the second group of less severely corroded specimens contains materials P, Q and R; and the third group of specimens showing very little corrosion contains materials J, S, T and V.

Section 3 on Corrosion in Hydrochloric Acid (L. L. Deitz, Jr., chairman):

Section 3 has not as yet completed any of its tests in hydrochloric acid. However, work has been started and results should be available next year.

Section 4 on Corrosion in Sulfuric Acid (Steel Pickle Solutions) (W. H. Scott, chairman):

Section 4 is testing materials A, C, D, H, J, K, L, M, N, P, Q, R, S, T, X and Y. Three series of tests have been completed during the past year, one series in each of the three test locations. The details of past tests are given in last year's report of the committee.[1] The present series of tests were conducted under conditions identical with those already described except in series D, test location No. 31. Red Dog flour was used as an inhibitor, while in series C, test location No. 33, Rodine at the rate of 1 qt. per 100 gal. of pickling solution was used. The results are given in Table III. All tests were conducted in a commercial iron pickle solution containing relatively large amounts of iron salts. It is quite possible that the iron salts are largely responsible for the corrosion of certain of the specimens. Tension tests on the specimens have not been completed but will be reported next year when a summarizing report completing the work of this section will be submitted.

Respectfully submitted on behalf of the subcommittee,

A. J. PHILLIPS,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 229 (1934).

REPORT OF SUBCOMMITTEE VIII ON GALVANIC AND ELECTROLYTIC CORROSION

The 1934 report[1] of Subcommittee VIII gave the results of the 1-yr. period in the test program undertaken to study the corrosion behavior of metals when in contact with dissimilar metals on outdoor exposures. The present report is a record of the corrosion which has occurred on the second set of couples exposed over a 3-yr. period.

Originally, four sets of disks arranged in couples were exposed in nine typical atmospheres, each set consisting of all the couple combinations of the following metals:

Identification Letter	Material
G	Aluminum (99.1 + per cent)
BB	Zinc (99.0 + per cent)
GG	Iron (mild steel)
U	Lead (99.9 + per cent)
EE	Tin (99.8 + per cent)
T	Nickel (99.3 per cent)
A	Copper (99.9 per cent)

There are still two complete sets of couples remaining on the test racks· These will be withdrawn and examined at some later date.

The 3-yr. couples covered in this report were exposed as follows:

Test Location	Atmosphere Classification	Exposure Period 1931	to 1934	Elapsed Time, years
La Jolla (San Diego), Calif	Southwestern seacoast	Sept. 1	Sept. 6	3.0
Sandy Hook, N. J	Northeastern seacoast	April 14	April 13	3.0
Key West, Fla	Southeastern seacoast	Oct. 12	Nov. 12	3.1
Pittsburgh, Pa	Industrial	July 8	July 6	3.0
Altoona, Pa	Industrial	June 1	June 1	3.0
Rochester, N. Y	Industrial (humid)	Sept. 21	Sept. 20	3.0
New York City	Industrial (seacoast)	March 23	March 22	3.0
Phoenix, Ariz	Rural	Sept. 4	Sept. 5	3.0
State College, Pa	Rural	June 8	June 8	3.0

Information regarding the meterological conditions at the test locations, metallurgical history of the metals, the preparation of the test couples, and the installation of the tests at the various locations is to be found in previous reports of Committee B-3.[2]

On receipt of the couples from the test locations, they were first tested for contact resistance by standard a.c. bridge methods except in the case of the New York City couples on which a buzzer test was used. The couples were then disassembled and arranged for visual inspection, after which the corrosion products were removed and the disks weighed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 236 (1934).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 214–241, pp. 248–251 (1932).

VISUAL INSPECTION

The visual inspection was made by a working committee consisting of three members of the subcommittee and the following items were recorded:

1. Amount, distribution and color of corrosion products on the disk edge and face.
2. Approximate percentage of disk face not covered by corrosion products.
3. Whether or not disk was deformed.
4. Whether or not corrosion products were formed on the outside of the disks.

REMOVAL OF PAINT AND CORROSION PRODUCTS

1. *Removal of Paint:*

The disks were first suspended in trichlorethylene vapor for 15 to 45 min., after which they were cleaned by rubbing with a cloth saturated with a paint remover consisting of five parts benzol, three parts acetone, one part alcohol and one part ether. The maximum weight loss on blank disks subjected to the treatment did not exceed 1.0 mg.

2. *Removal of Corrosion Products:*

The methods used to remove the corrosion products from the disks were as follows:

Iron.—The iron disks were immersed in a 20 per cent NaOH solution at boiling temperature, to which was added 200 to 300 g. of zinc dust per liter.[1] This bath was stirred and the disks placed so that they were kept in contact with the zinc dust. This process required from 10 min. to 1 hr. and 50 min., depending on the condition of the disks. The disks were then dipped for one to two minutes in a solution of HCl (1:1), containing 10 g. per liter of Rodine, at 10 to 15 C. This was followed by scrubbing under running water. One such treatment sufficed to remove the last visible traces of rust from the surface. This treatment applied to blank specimens showed no loss after a period of 2 hr. in the NaOH solution and an average loss of 1.0 mg. for 2.5 min. in the HCl solution.

Nickel.—The nickel disks were immersed in a solution of HCl (1:1), at 10 to 15 C., for $2\frac{1}{2}$ min. followed by scrubbing under running water. Several of the nickel disks which had been coupled to iron and two of those coupled to tin required a longer period of immersion, in no case totaling more than five minutes. This treatment applied to blank specimens showed a loss in weight of less than 1.0 mg. for a 15-min. period.

Aluminum.—All of the aluminum disks were cleaned in a solution of concentrated HNO_3 at room temperature for periods varying from 1 to $2\frac{1}{2}$

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[1] This process was described by Jean Cournat and Marcel Chaussain, *Comptes rendus*, Vol. 194, p. 1823 (1932), and T. F. Finnegan and R. C. Corey, "Removal of Corrosion Products from Iron," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. V, No. 2 (1933).

hr., followed by scrubbing under running water. The HNO_3 treatment applied to blank disks showed a loss of less than 1.0 mg. after 2½ hr.

It was found that the aluminum disks coupled with iron could not be entirely cleaned by the nitric acid method. These disks were then placed in HCl (1:1) for 10 min. at 10 to 15 C. This method had been successfully used on the 1-yr. disks and in the preliminary tests on blanks in which the weight loss did not exceed 5.0 mg. However, the 3-yr. specimen disks coupled with iron were so severely attacked by the hydrochloric acid treatment as to necessitate the omission of their data from the tables.

Tin.—The tin disks were given one to three 5-min. dips in a solution of HCl (1:1) at 10 to 15 C. followed by scrubbing under running water. Two specimens that had been coupled with iron required a total immersion of 50 min. in this solution. The treatment applied to blank specimens showed a loss of 1.0 mg. for a 15-min. period and 3.0 mg. for the 50-min. treatment. It was found that mechanical bending followed by additional immersion in HCl helped considerably to loosen a large amount of corrosion on a disk which had been coupled to iron.

Lead.—The lead disks were immersed in a solution of 1 per cent acetic acid at boiling temperature for a period of 2 min. In several cases additional dips of from 1 to 13 min. were necessary. The specimens that had been coupled to iron were, in addition to the above, immersed for 2 min. in a solution of HCl (1:1) at a temperature of 10 to 15 C. This was followed by scrubbing under running water. The acetic acid treatment applied to blank specimens showed a loss of 2.0 to 3.0 mg. after an immersion of 5 min. The maximum loss for five specimens subjected to the longer treatment was 8.0 mg. The HCl treatment produced a loss of 1.0 mg. It was found that mechanically bending the disks followed by additional immersion in acetic acid helped considerably to loosen corrosion products in a few severe cases. Two disks which had been coupled to aluminum could not be entirely cleaned by the above treatment. The corrosion, embedded in pits, was in the form of a white substance (probably insoluble salts of aluminum or lead). No solvent was found for this corrosion product.

Zinc.—The zinc disks were immersed for two minutes in H_2SO_4 (1:10) solution containing 1.2 g. per liter of $HgCl_2$ at room temperature. Some of the specimens, however, required 21 min. The specimens were treated in small vessels and the solution was changed often due to possible removal of the inhibitor (Hg) by precipitation. After treatment, the disks were scrubbed under running water. This treatment applied to blanks showed an increase in weight of 4.0 mg. for the 21-min. period.

Copper.—The copper disks were immersed in a solution of HCl (1:1) at 10 to 15 C. The specimens were dipped for one or two periods of 15 min. followed by scrubbing under running water. The treatment applied to blank specimens showed a loss of 1.0 mg. after an immersion of 30 min.

A solution of ammonium carbonate (saturated) was tried in an effort to remove a small amount of some remaining corrosion products, but these products were not attacked or loosened.

Final Check.—At the end of a complete cleaning process, five disks of each metal were chosen and put through the process for removal of corrosion products a second time to check the effect of the process on the cleaned metal. The specimens selected were the least attacked so as to minimize any error due to removal of minute quantities of corrosion that might have been recessed in pits. The average changes in weight are listed below with a brief explanation of treatment:

METAL	TREATMENT	CHANGE IN WEIGHT, MG.
Iron	30 min. 20 per cent NaOH, Zn 2 min. HCl (1:1) Rodine	Negligible
Nickel	2.5 min. HCl (1:1)	Negligible
Aluminum	30 min. concentrated HNO_3	Negligible
Zinc	15 min. H_2SO_4 (1:10) + $HgCl_2$	+1
Copper	15 min. HCl (1:1)	Negligible
Tin	10 min. HCl (1:1)	−1
Lead	2 min. $HC_2H_3O_2$ (1:100)	−2

WEIGHT MEASUREMENTS

After the corrosion products were removed, the disks were weighed to determine the weight changes due to loss of metal by corrosion. The error in the weight measurements due to the method of weighing, including the precision of the balance used, amounted to approximately 1.0 mg.

PRESENTATION OF DATA

The data from the visual inspection of the couples, the contact resistance measurements and the weight changes, corrected for cleaning errors, are given in Table I (Plate III). The difference between the weight change of each metal coupled with itself and coupled with other metals is given in the second weight column. A plus sign indicates that the normal corrosion has been accelerated and a minus sign indicates a retardation. The weight change data expressed as a percentage of the original weight of the disk are given in Table II.

The method of graphically presenting the weight change data used in the 1934 report was used with the present data in preparing Figs. 1 and 2. The graphs show the loss in weight as a percentage of the original weight of the disk so as to obtain a more accurate comparison of metals of different densities. In these figures, the results for the same metal are grouped together and the respective exposure locations indicated at the bottom of each group. Each disk of the group was coupled with the metal indicated by the chemical symbol over the column. For example, the group marked "Aluminum" shows the percentage losses in weight of the aluminum disks when coupled with zinc, lead, tin, nickel, copper, and iron, respectively.

TABLE I.- VISUAL INSPECTION, CO

Legend

Amount of Corrosion Products

T - Tarnish
S - Slight
M - Medium
H - Heavy
VH - Very Heavy

Extent of Corrosion Products

Sp - Spotty
Ge - General

Color of Corrosion Products

G - Green
Gr - Gray
B - Blue
Br - Brown
Bk - Black
W - White
N - Natural
Lt - Light
D - Dark

De - Deformed

% -- Per cent of disk area not covered with corrosion products.

(a)-- Difference between the average weight change of each metal coupled with itself and when coupled with other metal.

M -- Following a number in the resistance column indicates thousands; for example, 3.5 M means 3500.

Nominal Weights of Discs in Grams

Aluminum	4.6
Copper	14.9
Iron	12.8
Tin	12.4
Zinc	11.9
Nickel	14.6
Lead	19.1

Couple	La Jolla, Cal.							Sandy Hook, N. J.							Key West, Fla.							
	Edge	Face Amt	Face Color	%	Res Ohms	Wt. Loss Mg	Wt Diff Mg (a)	Edge	Face Amt	Face Color	%	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge	Face Amt	Face Color	%	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge
Al	S-GR	S-Ge	Gr	5	7 M	39	-	T-Gr	S-Sp	Gr	30	2.5	7	-	S-Gr	S-Sp	Gr	40	1.7	16	-	S-D Br
Al	S-Gr	S-Ge	Gr	5		66	-	T-Gr	S-Sp	Gr	30		10	-	S-Gr	S-Sp	Gr	40		12	-	S-D Br
Al	H-Gr	H-Ge	Gr G	0	7 M	462	+409	S-Gr	M-Ge	B Gr	0	Inf	203	+194	M-W	H-Ge	W-G	0	80 M	142	+128	M-Gr Br
Cu	H-GrG	M-Sp	Gr G	80		41	-102	S-Gr	S-Sp	Gr	30		26	+11	S-W Br	M-Ge	W-G Br	0		21	+7	S-D Br
Al	H-BrGr	H-Ge	Br Gr	0	3 M	***	***	T-Br	S-Ge	Br W	0	Inf	***	***	S-W Br	M-Ge	Br	0	9.0	***	***	S-D Br
Fe	H-Br	H-Ge	Br Gr	0		1258	-1684	M-Br	M-Ge	Br W	0		598	+79	S-Br	M-Ge	Br	0		311	-163	H-D Br
Al	M-Gr	H-Sp	Gr	5	1 M	214	+161	S-Gr	S-Ge	Gr	20	2 M	48	+39	S-W	M-Ge	W	10	1.7	51	+37	S-D Br
Sn	S-Gr	M-Ge	Gr	2*		32	-4	S-Gr	S-Ge	Gr	0		-	-	T-Gr	M-Sp	W	20		1	-24	S-D Br
Al	M-Gr	S-Sp	Gr	80	2.0	10	-43	T-Gr	T-Sp	Gr	10	5.0	1	-8	T-Gr	T-Sp	Gr	40	3.5	1	-13	T-D Br
Zn	H-Lt Gr	S-Ge	Gr Br	10**		697	+273	T-Gr	S-Sp	Gr	10		66	+26	S-Gr	S-Sp	Gr	30		44	+8	T-Gr Br
Al	M-Gr	H-Ge	Gr	0	2.6	286	+233	S-Gr	S-Sp	Gr-G	15	Inf	41	+32	S-Gr	M-Ge	W	5	3.0	50	+36	Ht-Bk
Ni	T-Gr	S-Sp	Gr	90		5	0	T-N	S-Sp	Gr	40		11	+3	T-W	S-Sp	W	60		0	-2	T-Bk
Al	S-Gr	H-Ge	Gr	0	Inf	215	+162	T-Gr	M-Ge	W	0	Inf	87	+78	S-Gr	M-Sp	Lt Gr	30	5 M	73	+59	S-D Br
Pb	S-Gr	S-Ge	Gr	0		76	-17	T-Gr	M-Sp	Gr	0		37	+7	S-Gr	S-Sp	Gr	20		80	-21	T-Br
Cu	S-G	M-Ge	Br Bk	0	1.7	136	-	T-Br	S-Sp	Br	90	1.7	13	-	T-Gr Br	T-Ge	Br	95	1.7	14	-	T-Bk
Cu	S-G	M-Ge	Br Bk	0		150	-	T-Br	S-Sp	Br	90		16	-	T-Gr Br	T-Ge	Br	95		14	-	T-Bk
Cu	S-Br	M-Ge	Br	0	35 M	120	-23	T-Br	M-Ge	Br	0	25	27	+12	T-Br	M-Ge	Br	0	20.0	19	+5	S-D Br
Fe	VH-D Br	H-Ge	Br	0		4278	+1356	M-Br	M-Ge	Br	0		649	+130	M-D Br	M-Ge	D Br	0		819	+345	H-Br
Cu	S-Gr	S-Sp	G Bk	0.5	1.8	21	-122	S-Br	S-Ge	Br-B	5	1.7	20	+6	T-W Br	S-Ge	Br Bk	20	1.7	16	+2	S-Bk
Sn	H-Gr	S-Sp	G Bk	10		357	+321	S-Br	S-Sp	Lt Br	70		51	+36	S-Gr	S-Ge	Bk	20		107	+82	T-Bk
Cu	M-Gr	M-Ge	Gr Bk	2	Inf	26	-117	T-Gr Br	S-Ge	Gr Br	2	1.7	12	-3	T-Gr	S-Ge	Gr Ck	5	1.7	14	0	T-Br
Zn	H-Gr	M-Ge	Gr Bk	2		953	+529	T-Gr	S-Ge	Gr	5		100	+60	T-Gr	S-Sp	Gr	20		71	+35	S-Gr
Cu	H-G	M-Ge	Gr Bk	0.5	45 M	429	+286	T-Br	T-Ge	Br	90	1.8	19	+4	T-Br Gr	T-Ge	Br	95	3.0	20	+6	T-Bk
Ni	S-GrG	S-Sp	Bk G	95		4	-1	T-Br	T-Ge	N	95		7	-1	T-H	T-Ge	N	98		1	-1	T-Bk
Cu	S-Gr	S-Ge	Bk B	5	3.5	44	-99	T-Gr Br	T-Ge	Br Gr	85	3.5	8	-7	S-Gr	S-Ge	Gr Br	10	Inf	9	-5	S-D Br
Pb	M-BrGr	M-Ge	Br B	0		295	+202	T-D Gr	T-Ge	D Gr	75		42	+12	S-Gr	T-Sp	D Gr	50		115	+14	T-Br
Fe	VH-Br	VH-Ge	Br	0**	Inf	2684	-	S-Br	M-Ge	Gr	0	Inf	525	-	M-Br	M-Ge	Br	0	Inf	453	-	H-Br
Fe	VH-Br	VH-Ge	Br	0**		3199	-	S-Br	M-Ge	Br	0		513	-	M-Br	M-Ge	Br	0		495	-	H-Br
Fe	VH-Br	H-Ge	Br	20**	1.7	2353	-589	S-Br	M-Ge	Br	2	Inf	511	-8	M-Br	M-Ge	Br	50	1.8	283	-191	H-Br
Sn	S-Gr	H-Ge	Br	40**		347	+311	S-Br	S-Ge	Br Gr De	1		64	+49	S-Gr	S-Ge	Br De	50		165	+140	S-D Br
Fe	M-Br	M-Sp	Br	20**	9 M	494	-2448	S-Gr	S-Ge	Lt Br	10	4.0	8	-511	S-Gr Br	S-Ge	Gr Br	5	5.0	15	-459	S-Br
Zn	H-Gr	M-Sp	Gr Br	1**		1072	+648	S-Gr	S-Ge	Gr	5		101	+61	S-Gr	S-Ge	Gr	2		102	+66	T-Br
Fe	H-Br	H-Ge	Br	0**	8 M	2984	+42	M-Br	M-Ge	Br	0	Inf	534	+15	M-D Br	M-Ge	D Br	10	Inf	561	+87	H-D Br
Ni	S-Br	S-Sp	Br	10		25	+20	T-Br	S-Sp	Br	5		12	+4	T-Br	S-Sp	Br	20		5	+3	S-Br
Fe	H-Br	H-Ge	Br	0**	Inf	2783	-159	S-D Br	M-Ge	Br	0	Inf	381	-138	S-Br	S-Ge	Br	20	Inf	212	-262	H-Br
Pb	S-Br	H-Ge	Br De	0		160	+67	S-Br	S-Ge	Br	5		68	+38	T-W Br	S-Ge	Br	20		138	+37	T-Bk
Sn	T-Gr	T-Ge	Gr	-	1.7	35	-	S-Gr	T-Sp	Gr	90	1.7	14	-	T-Gr	T-Ge	B Gr	95	1.7	28	-	S-Br
Sn	T-Gr	T-Ge	Gr	-		37	-	S-Gr	T-Sp	Gr	90		15	-	T-Gr	T-Ge	B Gr	95		21	-	S-Br
Sn	M-Gr	S-Sp	Gr	50	1.7	25	-11	T-N	T-Ge	N	98	1.7	7	-8	T-Gr	T-Sp	Gr	50	1.7	0	-25	T-Bk
Zn	H-Gr	S-Sp	Gr	10**		847	+423	S-Gr	T-Sp	Lt Gr	80		56	+16	S-Gr	S-Ge	Gr	20		48	+12	T-Gr
Sn	S-Gr	S-Ge	Gr	10	1.7	134	+98	T-Gr	T-Sp	Gr	50	1.7	21	+6	S-Gr	T-Ge	D Gr	80	1.7	18	-7	T-Br
Ni	S-Gr	S-Ge	Gr	10		1	-4	T-Gr	T-Sp	Gr	60		8	0	T-N	T-Ge	D Tint	90		1	-1	T-Br
Sn	S-Gr	S-Sp	Gr	10	1.7	41	+5	S-Gr	T-Ge	Lt Br	60	1.7	9	-6	S-Gr	T-Sp	Gr	50	Inf	11	-14	T-Bk
Pb	S-Gr	S-Sp	Gr De	95		77	-16	T-Br	T-Ge	Br	50		36	+6	S-Gr	T-Ge	Gr	30		126	+25	T-Bk
Zn	H-Gr	M-Ge	Gr Bk	5**	1.7	370	-	T-Gr	T-Sp	Gr	90	1.7	33	-	S-Gr	S-Sp	Gr	80	1.6	40	-	S-Br
Zn	H-Gr	M-Ge	Gr Bk	5**		478	-	T-Gr	T-Sp	Gr	90		47	-	S-Gr	S-Sp	Gr	80		31	-	S-Br
Zn	H-Gr	M-Ge	Gr Bk	1	1.7	1492	+1068	T-Gr	S-Sp	Gr	20	4.5	70	+30	S-Gr	S-Ge	Gr	20	4.0	56	+20	T-Gr
Ni	S-Gr	S-Sp	Gr	40		2	-3	T-Br	S-Ge	Gr	15		2	-6	S-Gr	S-Ge	Gr	20		0	-2	T-Bk
Zn	S-Gr	M-Ge	Gr	5	1.7	1314	+890	S-Gr	T-Ge	Gr	20	1.7	186	+146	S-Gr	S-Ge	Gr	10	5.0	51	+15	S-Gr
Pb	H-Gr	M-Ge	Gr Bk	2**		296	+203	T-Gr	T-Ge	Gr W De	10		73	+43	S-Gr	S-Ge	Gr	5		108	+7	T-Br
Ni	T-N	S-Ge	G	90	1.8	3	-	T-Br	T-Sp	B Tint	98	2.5	8	-	T-N	T-Sp	Lt G	98	1.8	2	-	T-Bk
Ni	T-N	S-Ge	G	90		6	-	T-Br	T-Sp	B Tint	98		8	-	T-N	T-Sp	Lt G	98		2	-	T-Bk
Ni	T-N	S-Sp	Gr	20	2.1	3	-2	T-Gr	T-Ge	Gr	90	Inf	6	-2	T-N	T-Ge	W	95	Inf	0	-2	T-D Br
Pb	S-Gr	S-Sp	Gr	20		201	+180	T-N	T-Ge	D Gr	70		36	+6	S-Gr	S-Ge	Gr	10		113	+12	T-Br
Pb	T-Gr	T			1.8	96	-	T-D Gr	T-Ge	D Gr	50	Inf	31	-	T-Gr	T-Ge	Gr	30	Inf	102	-	T-Bk
Pb	T-Gr	T				89	-	T-D Gr	T-Ge	D Gr	50		29	-	T-Gr	T-Ge	Gr	30		100	-	T-Bk

*Hole corroded through sample.

**Corrosion products on back face.

TABLE I.- VISUAL INSPECTION, CONTACT RESISTANCE AND WEIGHT LOSS OF METAL DISKS IN GALVANIC COUPLE CORROSION TEST AFTER 3-YR. EXPOSURE.

k, N. J.				Key West, Fla.						Pittsburgh Pa						Altoona Pa						Rochester		
%	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge	Face Amt Color	Face %	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge	Face Amt Color	Face %	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge	Face Amt Color	Face %	Res Ohms	Wt Loss Mg	Wt Diff Mg (a)	Edge	Face Amt Color	Face %
30	2.5	7	-	S-Gr	S-Sp Gr	40	1.7	16	-	S-D Br	S-Sp Gr	50	1.7	4	-	S-D Br	S-Sp Gr	30	1.8	10	-	T-Br	T-Sp Gr	80
30		10	-	S-Gr	S-Sp Gr	40		12	-	S-D Br	S-Sp Gr	50		6	-	S-D Br	S-Sp Gr	30		9	-	T-Br	T-Sp Gr	80
0	Inf	203	+194	M-W	H-Ge W-G	0	80 M	142	+128	M-Gr Br	T-Sp N	98	1.7	11	+6	S-Gr Bk	M-Ge W-G	2	4.0	80	+70	S-D Br	S-Sp G	95
30		26	+ 11	S-W Br	M-Ge W-G Br	0		21	+7	S-D Br	T-Ge N	98		13	-27	T-D Br	M-Sp Lt G-Br	5		7	-21	T-D Br	T-Ge Br	80
0	Inf	***	***	S-W Br	M-Ge Br	0	9.0	***	***	S-D Br	M-Ge Br	0	1.8	***	***	S-D Br	M-Ge Br	5	Inf	***	***	S-Br	S-Sp Br Gr	10
0		598	+79	S-Br	M-Ge Br	0		311	-163	H-D Br	M-Ge Br	0		424	-337	M-D Br	M-Ge Br	0		401	-80	S-Br	S-Ge Br Gr	5
20	2 M	48	+39	S-W	M-Ge W	10	1.7	51	+37	S-D Br	S-Sp Gr	40	1.8	9	+4	S-Gr Br	M-Sp Gr	10	1.0	21	+11	S-D Gr	T-Sp Gr	75
0		-	-	T-Gr	M-Sp W	20		1	-24	S-D Br	S-Sp Gr	30		0	-16	T-D Gr	S-Sp Gr Bk	10		4	-11	T-D Gr	T-Sp Gr	75
10	5.0	1	-8	T-Gr	T-Sp Gr	40	3.5	1	-13	T-D Br	S-Sp Gr	40	1.7	0	-5	S-D Br	T-Sp Gr	80	Inf	4	-6	T-Gr	T-Sp Gr	98
10		66	+26	S-Gr	S-Sp Gr	30		44	+8	T-Gr Br	S-Ge Gr	30		85	+24	S-D Br	T-Sp Gr	80		60	+4	T-Gr	T-Sp Gr	98
15	Inf	41	+32	S-Gr	M-Ge W	5	3.0	50	+36	Ht-Bk	S-Sp G Gr	80	1.8	9	+4	S-Gr Br	M-Ge Gr W	5	50 M	46	+36	S-D Br	T-Sp Gr	98
40		11	+3	T-W	S-Sp W	60		0	-2	T-Bk	S-Sp Bk Gr	10		15	-15	T-D Br	S-Sp Gr W	20		11	-18	T-D Br	T-Ge Gr	98
0	Inf	87	+78	S-Gr	M-Sp Lt Gr	30	5 M	73	+59	S-D Br	S-Sp D Gr	40	3.0	5	0	M-D Br	M-Ge Gr Br	10	3.5	53	+43	S-D Gr	T-Sp B Tint	50
0		37	+7	S-Gr	S-Sp Gr	20		80	-21	T-Br	T-Sp D Br	40		35	-5	S-D Br	M-Ge Gr DBr	10		39	+12	T-D Gr	T-Ge D Gr	50
90	1.7	13	-	T-Gr Br	T-Ge Br	95	1.7	14	-	T-Bk	T-Ge Bk	5	1.7	39	-	S-D Br	T-Ge D Br	80	3.0	27	-	T-Bk	T-Ge Br	95
90		16	-	T-Gr Br	T-Ge Br	95		14	-	T-Bk	T-Ge Bk	5		41	-	S-D Br	T-Ge D Br	80		28	-	T-Bk	T-Ge Br	95
0	25	27	+12	T-Br	M-Ge Br	0	20.0	19	+5	S-D Br	H-Ge Br	2	3.0	40	0	S-D Br	M-Ge Br	2	10	23	-5	S-Br	T-Sp Br G	50
0		649	+130	M-D Br	M-Ge D Br	0		819	+345	H-Br	H-Ge Br	2		1309	+548	H-Br	M-Ge Br	2		682	*201	H-D Br	T-Sp Br G	30
5	1.7	20	+5	T-W Br	S-Ge Br Bk	20	1.7	16	+2	S-Bk	S-Ge Bk	20	1.7	50	+10	S-D Br	T-Sp D Br G	50	1.7	30	+2	T-D Br	T-Sp Br	80
70		51	+36	S-Gr	S-Ge Bk	20		107	+82	T-Bk	S-Ge D Gr	30		63	+47	S-D Br	S-Ge D G-Br	50		46	+31	T-Br	S-Sp DG	85
2	1.7	12	-3	T-Gr	S-Ge Gr Ck	5	1.7	14	0	T-Br	S-Sp Gr	30	1.7	4	-36	S-Br	T-Sp Br	90	1.9	4	-24	S-Br	T-Sp Br Gr	90
5		100	+60	T-Gr	S-Sp Gr	20		71	+35	S-Gr	S-Sp Gr	30		111	+50	S-Gr	T-Sp Gr	90		89	+33	S-D Gr	T-Sp Gr	90
90	1.8	19	+ 4	T-Br Gr	T-Ge Br	95	3.0	20	+6	T-Bk	S-Ge G-Br	25	3.0	8	-32	S-D Br	T-Ge Br	98	4.0	19	-9	T-D Br	T-Ge D Br	90
95		7	-1	T-H	T-Ge N	98		1	-1	T-Bk	S-Sp G	90		73	+43	S-D Br	T-Ge B Tint	98		35	+6	T-D Br	T-Ge Br	95
85	3.5	8	-7	S-Gr	S-Ge Gr Br	10	Inf	9	-5	S-D Br	T-Ge Br	80	3.5	49	+9	S-D Br	S-Ge Br	80	3.0	24	-4	S-D Br	T-Sp Br	90
75		42	+12	S-Gr	T-Sp D Gr	50		115	+14	T-Br	T-Ge D Br	90		44	+6	S-D Br	S-Ge D Br	80		34	+7	T-D Br	T-Sp D Gr	60
0	Inf	525	-	M-Br	M-Ge Br	0	Inf	453	-	H-Br	H-Ge Br	0	Inf	785	-	M-Br	M-Ge Br	1	Inf	498	-	H-Br	M-Ge Br	5
0		513	-	M-Br	M-Ge Br	0		495	-	H-Br	H-Ge Br	0		737	-	M-Br	M-Ge Br	1		463	-	H-Br	M-Ge Br	5
2	Inf	511	-8	M-Br	M-Ge Br	50	1.8	283	-191	H-Br	M-Ge Br	5	5.0	1114	+353	M-Br	M-Ge Br	2	5.0	571	+90	H-Br	H-Ge Br	5
1		64	+49	S-Gr	S-Ge Br De	50		165	+140	S-D Br	H-Ge D-Br De	5		48	+32	S-Br	M-Ge Br De	5		36	+21	S-D Br	M-Sp Br De	15
10	4.0	8	-511	S-Gr Br	S-Ge Gr Br	5	5.0	15	-459	S-Br	S-Sp Br W	10	5 M	27	-734	S-Br	S-Sp Gr Br	40	4.0	16	-465	T-D Br	T-Sp Br Gr	20
5		101	+61	S-Gr	S-Ge Gr	2		102	+66	T-Br	S-Sp Br W	5		119	+58	S-Br Gr	S-Sp Gr	40		107	+51	T-Gr	T-Sp W	30
0	Inf	534	+15	M-D Br	M-Ge D Br	10	Inf	561	+87	H-D Br	H-Ge Br	0	Inf	877	+116	M-Br	H-Ge Br	2	Inf	516	+35	H-Br	M-Sp Br	30
5		12	+4	T-Br	S-Sp Br	20		5	+3	S-Br	S-Sp Br	20		43	+13	S-Br	M-Sp Br	30		23	-6	S-Br	S-Sp Br	40
0	Inf	361	-138	S-Br	S-Ge Br	20	Inf	212	-262	H-Br	H-Ge Br	20	6.0	881	+120	M-Br	M-Ge Br	30	4.5	435	-46	H-Br	H-Ge Br	15
5		68	+38	T-W Br	S-Ge Br	20		138	+37	T-Bk	M-Ge Br De	20		74	+36	S-D Br	S-Ge D Br De	30		52	+25	T-Gr	S-Sp Br De	15
90	1.7	14	-	T-Gr	T-Ge B Gr	95	1.7	28	-	S-Br	S-Sp Gr Br	60	1.7	17	-	S-D Br	S-Ge D Br	80	1.7	14	-	S-D Gr	T-Sp Gr	75
90		15	-	T-Gr	T-Ge B Gr	95		21	-	S-Br	S-Sp Gr Br	60		15	-	S-D Br	S-Ge D Br	80		16	-	S-D Gr	T-Sp Gr	75
98	1.7	7	-8	T-Gr	T-Sp Gr	50	1.7	0	-25	T-Bk	S-Sp Gr	20	1.7	3	-13	S-D Br	S-Sp D Br W	80	1.7	2	-13	T-D Gr	S-Sp Gr	95
80		56	+16	S-Gr	S-Ge Gr	20		48	+12	T-Gr	S-Sp Gr	30		89	+28	S-D Br	S-Sp Gr DBr	70		79	+23	T-D Gr	T-Sp W	50
50	1.7	21	+6	S-Gr	T-Ge D Gr	80	1.7	18	-7	T-Br	S-Sp Gr Br	60	1.7	10	-6	S-Br	S-Ge Br	80	4.0	14	-1	S-d Gr	T-Sp B Tint	90
60		8	0	T-W	T-Ge D Tint	90		1	-1	T-Br	S-Sp Gr Br	60		34	+4	S-Br	S-Ge Br	80		27	-2	S-D Gr	T-Sp B Tint	90
60	1.7	9	-6	S-Gr	T-Sp Gr	50	Inf	11	-14	T-Bk	S-Sp Br	60	2.8	21	+5	S-D Br	S-Sp D Br	80	Inf	12	-3	T-D Gr	T-Sp D Gr	90
50		36	+6	S-Gr	T-Ge Gr	30		126	+25	T-Bk	S-Sp D Br	30		46	+6	S-D Br	S-Ge D Br	80		50	+23	T-D Gr	T-Ge D Gr	60
90	1.7	33	-	S-Gr	S-Sp Gr	80	1.6	40	-	S-Br	S-Sp Gr Br	30	1.8	65	-	S-Gr	T-Sp Gr	80	Inf	57	-	S-D Gr	T-Sp Gr	90
90		47	-	S-Gr	S-Sp Gr	80		31	-	S-Br	S-Sp Gr Br	30		56	-	S-Gr	T-Sp Gr	80		55	-	S-D Gr	T-Sp Gr	90
20	4.5	70	+30	S-Gr	S-Ge Gr	20	4.0	56	+20	T-Gr	S-Sp Gr	38	11.0	97	+36	S-Gr	S-Ge Gr	75	1.7	87	+31	T-D Gr	S-Ge W	70
15		2	-6	S-Gr	S-Ge Gr	20		0	-2	T-Bk	S-Sp Gr	30		3	-27	S-D Br	T-Sp Gr	90		4	-25	T-D Gr	S-Sp W	60
20	1.7	186	+146	S-Gr	S-Ge Gr	10	5.0	51	+15	S-Gr	S-Sp Gr Br	30	Inf	108	+47	S-Gr	T-Sp Gr	60	1.8	96	+39	S-Gr	S-Sp Gr	40
10		73	+43	S-Gr	S-Ge Gr	5		108	+7	T-Br	S-Sp Gr Br	30		48	+10	S-Br	T-Sp Gr	50		24	-3	S-Br	S-Sp Gr W	40
98	2.5	8	-	T-W	T-Sp Lt G	98	1.8	2	-	T-Bk	S-Sp G	90	1.8	32	-	S-D Br	T-Ge D Br	95	1.8	29	-	T-D Br	T-Ge B Tint	90
98		8	-	T-W	T-Sp Lt G	98		2	-	T-Bk	S-Sp G	90		28	-	S-D Br	T-Ge D Br	96		28	-	T-D Br	T-Ge B Tint	90
90	Inf	6	-8	T-W	T-Ge W	95	Inf	0	-2	T-D Br	T-Sp Br	80	Inf	31	+1	S-D Br	T-Ge Gr	80	2.5	22	-7	S-Br	T-Sp Gr	80
70		36	+6	S-Gr	S-Ge Gr	10		113	+12	T-Br	T-Sp Br De	30		73	+35	S-D Br	T-Ge D Gr	75		28	+1	S-Gr	T-Ge N	50
60	Inf	31	-	T-Gr	T-Ge Gr	30	Inf	102	-	T-Bk	T-Ge Bk	60	1.7	34	-	S-D Br	T-Ge D Gr De	80	1.7	27	-	T-D Gr	T-Ge N	80
50		29	-	T-Gr	T-Ge Gr	30		100	-	T-Bk	T-Ge Bk	60		42	-	S-D Br	T-Ge D Gr De	80		26	-	T-D Gr	T-Ge N	80

**Corrosion products on back face.

***Specimens destroyed by HCl treatment.

REPORT OF COMMITTEE B-3:
GALVANIC COUPLE CORROSION TESTS

EXPOSURE.

ochester N Y					New York City						Phoenix Aris.						State College Pa						
olor	%	Res Ohms	Wt Loss Mg	Wt Diff Mg(a)	Edge	Face Amt Color	Face %	*	Wt Loss Mg	Wt Diff Mg(a)	Edge	Face Amt Color	Face %	Res Ohms	Wt Loss Mg	Wt Diff Mg(a)	Edge	Face Amt Color	Face %	Res. Ohms	Wt. Loss Mg	Wt Diff Mg(a)	Couple
	80	1.7	-	-	T-Gr	S-Ge Lt Gr	40	OK	8	-	T-N	T-Sp N	80	1.8	0	-	T-GeN	T-Ge N	-	2.4	0	-	Al
	80		0	-	T-Gr	S-Ge Lt Gr	40		6	-	T-N	T-Sp N	80		0	-	T-GeN	T-Ge N	-		0	-	Al
	95	1.7	10	+10	S-Br	M-Ge Gr G	5	OK	100	+93	S-Gr	S-Ge Gr	90	1.7	8	+8	S-DeGr	M-Sp Gr	50	1.8	9	+9	Al
	80		10	-7	S-Br	S-Sp Gr Br	10		12	-15	S-Gr	S-Ge Gr	90		2	-2	S-GeGr	M-Sp Gr	50		2	-5	Cu
Gr	10	1.8	***	***	S-Br	S-Sp Br	5	High	***	***	T-N	S-Sp Br	80	1.8	***	***	T-GeBr	M-Sp Gr Br	5	1.9	***	***	Al
Gr	5		316	-169	H-Br	H-Ge Br	0		779	+161	S-Br	S-Sp Br	20		33	-13	M-SpBr	M-Ge Gr Br	2		184	-16	Fe
	75	1.9	0	0	S-D Gr	S-Sp Gr	40	High	26	+19	T-Gr	S-Sp Gr	60	1.8	2	+2	T-N	S-Sp Gr	55	1.8	2	+2	Al
	75		2	-6	S-Br	S-Ge Gr	20		2	-8	T-Gr	S-Sp Gr	70		0	-2	T-N	S-Sp Gr	55		1	-4	Sn
	98	2.5	0	0	S-Gr	S-Ge Lt Gr	60		2	-5	T-N	S-Sp Gr	40	1.7	1	+1	T-N	S-Ge Gr	2	Inf	0	0	Al
	98		25	+5	S-D Gr	S - Ge Gr	5		86	+28	T-N	S-Sp Gr	40		11	+3	T-LtBr	W-Sp Gr	40		26	+14	Zn
	98	1.8	3	+3	S-D Gr	S-Sp Gr	15	High	21	+14	T-Gr	S-Sp Gr	90	1.8	1	+1	T-N	S-Sp Gr	60	1.7	8	+8	Al
	98		5	-4	S-Br	S-Sp Gr	10		11	-15	OK	Tarnish	100		1	0	T-LtBr	S-Sp Gr	55		3	0	Ni
int	50	2.0	3	+3	S-Gr	S-Sp Gr	30	OK	8	+1	T-N	S-Sp Gr	90	Inf	2	+2	T-N	S-Sp Gr	50	2.5	0	0	Al
r	50		47	-2	T-Gr	S-Sp Gr W	50		31	-6	T-N	S-Sp Gr	90		59	-1	T-Br	S-Sp Gr	60		36	+8	Pb
	95	1.9	19	-	T-Br	T-Sp Br	90	OK	25	-	T-N	T-Ge N	100	1.6	4	-	T-Br	T-Ge N	2	1.9	7	-	Cu
	95		14	-	T-Br	T-Sp Br	90		28	-	T-W	T-Ge N	100		3	-	T-Br	T-Ge N	2		6	-	Cu
G	50	1.8	11	-6	S-D Br	M-Ge Br	1	Poor	22	-5	T-Br	S-Ge Br	90	2.0	7	+3	S-Br	M-Ge Br	60	Inf	21	+14	Cu
G	30		430	-55	H-Br	M-Ge Br	0		829	+211	S-Br	S-Ge Br	80		38	-8	M-Br	M-Ge Br	50		223	+23	Fe
	80	1.7	17	0	S-D Br	S-Sp Br	20		21	-6	T-Br	T-Sp Br	15	1.7	5	+1	T-Br	S-Sp Lt Br	70	1.7	6	-1	Cu
	85		28	+20	S-Br	S-Sp Gr G	30		37	+27	T-Gr	S-Sp Gr	90		6	+4	T-Gr	S-Ge D Gr	65		13	+8	Sn
Gr	90	1.7	3	-14	S-Br G	S-Ge Br G	90	OK	9	-18	T-Gr	S-Sp Gr	80	2.0	3	-1	T-Br	T-Ge Gr	95	2.0	3	-4	Cu
	90		37	+17	S-D Gr	T-Sp Gr	80		99	+41	T-Gr	S-Sp Gr	80		17	+9	T-N	T-Ge Gr	90		23	+11	Zn
r	90	10	12	-5	S-Br	T-Sp Br	90	OK	20	-7	T-Br	T-Ge N	100	1.7	4	0	T-Br	T-Ge N	98	1.7	8	+1	Cu
	95		7	-2	S-Br	T-Sp B Tint	95		42	+16		Unaffected			1	0	T-N	T-Ge N	100		2	-1	Ni
	90	40 M	19	+2	S-D Br	T-Ge G Br	75	OK	27	0	T-Gr	T-Sp Gr	90	1.6	6	+2	T-Br	T-Ge Lt Br	95	1.7	5	-2	Cu
r	60		45	-4	S-D Gr	S-Sp Gr	80		34	-3	T-Gr	T-Sp Gr	90		43	-17	S-Gr	T-Sp Gr	90		42	+14	Pb
	5	80 M	518	-	H-Br	M-Ge Br	0	High	624	-	S-Br	M-Sp Br	10	1.9	47	-	M-Br	M-Sp Br	10	Inf	203	-	Fe
	5		452	-	H-Br	M-Ge Br	0		612	-	S-Br	M-Sp Br	10		44	-	M-Br	M-Sp Br	10		197	-	Fe
	5	1.9	719	+234	H-Br	M-Ge Br	35	OK	767	+149	S-Br	S-Ge Br	30	1.7	70	+24	M-Br	M-Ge Br	5	1.8	303	+103	Fe
De	15		26	+18	S-D Br	S-Ge Br De	35		29	+19	T-N	S-Ge Br	30		13	+11	T-N	M-Ge Br De	5		12	+7	Sn
Gr	20	4.0	4	-481	S-Gr	S-Sp Gr Br	30	OK	3	-615	S-BrGr	S-Sp Gr	20	1.9	1	-45	S-Br	S-Ge Br	2	34.0	62	-138	Fe
	30		50	+30	S-Gr	S-Sp Gr	30		103	+45	T-Gr	S-Sp Gr	10		23	+15	T-Br	S-Sp Br	5		56	+44	Zn
	30	1.7	489	+4	M-Br	H-Ge Br	0	High	824	+206	S-Br	S-Sp Br	20	1.7	54	+8	M-Br	M-Sp Br	5	Inf	255	+53	Fe
	40		8	-1	S-D Br	M-Sp Br	20		24	-2	T-Br	S-Sp Br	40		2	+1	T-Br	S-Sp Br	20		3	0	Ni
	15	Inf	687	+202	H-Br	M-Ge Br	30	OK	625	+7	S-Br	S-Ge Br	90	Inf	37	-9	S-Br	S-Ge Br	40	7.0	122	-78	Fe
De	15		78	+29	S-Br	S-Ge Br De	30		64	+27	T-Br	S-Ge Br	95		41	-19	T-Br	S-Ge Br	40		76	+48	Pb
	75	1.7	8	-	S-Br	T-Sp Gr	95	OK	10	-	T-Gr	T-Ge B-Gr	-	1.7	8	-	T-N	T-Ge B Tint	100	1.7	6	-	Sn
	75		7	-	S-Br	T-Sp Gr	95		10	-	T-Gr	T-Ge B-Gr	-		1	-	T-N	T-Ge B Tint	100		4	-	Sn
	95	1.7	0	-8	T-Br	T-Sp Gr	60	OK	1	-9	T-Gr	S-Sp Gr	90	1.7	0	-2	T-Br	S-Ge Gr	30	1.7	0	-5	Sn
	50		30	+10	T-Br	T-Sp Gr	60		87	+29	T-N	S-Sp Gr	90		13	+5	T-Gr	S-Ge Gr	30		27	+15	Zn
nt	90	1.7	6	-2	S-Gr	T-Sp Gr	95	OK	12	+2	T-N	T-Ge B-Gr	-	1.7	2	0	T-Gr	S-Sp B Tint	50	1.8	6	+1	Sn
nt	90		11	+2	S-Br	T-Sp B Tint	95		27	+1	T-N	T-Ge B-Gr	-		1	0	T-Gr	S-Sp B Tint	50		3	0	Ni
	90	1.7	6	-2	S-D Gr	T-Sp Gr	90	OK	13	+3		Slight Tarnish		2.8	0	-2	T-Gr	S-Ge Gr	60	1.7	0	-5	Sn
	60		49	0	S-D Gr	T-Sp Gr	90		30	-7	T-Bk	S-Sp Gr	99		41	-19	S-Gr	S-Ge D Gr	60		43	+15	Pb
	90	1.7	20	-	S-Gr	T-Sp Gr	30	OK	54	-	T-N	T-Sp Gr	80	3.7	8	-	T-N	S-Sp Gr	90	1.7	12	-	Zn
	90		19	-	S-Gr	T-Sp Gr	30		62	-	T-N	T-Sp Gr	80		8	-	T-N	S-Sp Gr	90		11	-	Zn
	70	1.7	33	+13	S-Gr	T-Sp Gr	80	CK	88	+30	T-Gr	S-Sp Gr	20	1.5	15	+7	T-Br	T-Sp Lt Gr	90	1.8	17	+5	Zn
	60		1	-8	S-Br	T-Sp Gr	90		3	-23	T-Gr	S-Sp Gr	20		1	0	T-Br	T-Sp Lt Gr	90		1	-2	Ni
	40	2.2	33	+13	S-Gr	T-Sp Lt Gr	30	OK	91	+33	T-N	S-Sp Gr	90	12.0	13	+5	T-Gr	T-Sp Gr	75	3.5	18	+6	Zn
	40		51	+2	S-Gr	T-Ge Gr	20		26	-11	T-N	S-Sp Gr	90		35	-25	T-N	S-Sp Gr	75		32	+4	Pb
t	90	1.7	9	-		Slight tarnish		OK	25	-		Unaffected		1.7	1	-	T-Gr	T-Sp N	100	1.7	2	-	Ni
t	90		9	-		Natural Color			27	-		Unaffected			1	-	T-Gr	T-Sp N	100		3	-	Ni
	80	25	9	0	S-D Gr	T-Sp Gr	80	OK	29	+3	None	T-Sp Gr	95	Inf	0	-1	T-Gr	T-Sp Gr	90	3.5	2	-1	Ni
	50		64	+15	S-Gr	T-Ge W	90		50	+13	None	T-Sp Gr	95		34	-26	S-Gr	T-Sp D Gr	80		34	+6	Pb
	80	Inf	47	-	T-N	T-Ge N	90	OK	28	-	None	Tarnish		Inf	62	-	S-Gr	S-Sp Gr	75	1.8	27	-	Pb
	80		50	-	T-N	T-Ge N	90		46	-	None	Tarnish			57	-	S-Gr	S-Sp Gr	75		28	-	Pb

TABLE II.—GALVANIC COUPLE CORROSION TEST, 3-YR. EXPOSURE WEIGHT LOSS OF DISKS EXPRESSED AS PERCENTAGE OF ORIGINAL WEIGHT.

0.0—Weight change less than 0.06 per cent
X—Couple action negligible
A—Corrosion of disk accelerated by couple action
P—Corrosion of disk retarded

Metal	When Coupled With	La Jolla	Sandy Hook	Key West	Pittsburgh	Altoona	Rochester	New York City	Phoenix	State College
Aluminum Disks......	Blanks	0.9- 1.4	0.2- 0.2	0.3- 0.3	0.1- 0.1	0.2- 0.2	0.0-	0.2- 0.1	0-0	0-0
	Average	1.1	0.2	0.3	0.1	0.2		0.1		
	Zinc	0.2 P	0.0 P	0.0 P	0.0 X	0.1 X	0.0 X	0.0 X	0.0 X	0.0 X
	Lead	4.7 A	1.9 A	1.6 A	0.1 X	1.2 A	0.1 X	0.2 X	0.0 X	0.0 X
	Tin	4.6 A	1.1 A	1.1 A	0.2 X	0.5 A	0.0 X	0.6 A	0.0 X	0.0 X
	Nickel	6.2 A	0.9 A	1.1 A	0.2 X	1.0 A	0.1 X	0.5 A	0.0 X	0.2 A
	Copper	10.1 A	4.4 A	3.1 A	0.2 X	1.7 A	0.2 A	2.2 A	0.2 X	0.2 A
	Iron	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Zinc Disks...	Blanks	3.1- 4.0	0.3- 0.4	0.3- 0.3	0.5- 0.5	0.5- 0.5	0.2- 0.2	0.5- 0.5	0.1- 0.1	0.1- 0.1
	Average	2.5	0.3	0.3	0.5	0.5	0.2	0.5	0.1	0.1
	Aluminum	5.8 A	0.5 A	0.4 X	0.7 A	0.5 X	0.2 X	0.7 A	0.1 X	0.2 X
	Lead	11.0 A	1.5 A	0.4 X	0.9 A	0.8 A	0.3 X	0.8 A	0.1 X	0.1 X
	Tin	7.1 A	0.5 A	0.4 X	0.7 A	0.7 A	0.2 X	0.7 A	0.1 X	0.2 X
	Nickel	12.5 A	0.6 A	0.5 A	0.8 A	0.7 A	0.3 X	0.7 A	0.1 X	0.1 X
	Copper	8.0 A	0.8 A	0.6 A	0.9 A	0.7 A	0.3 X	0.8 A	0.1 X	0.2 X
	Iron	8.9 A	0.8 A	0.8 A	1.0 A	0.9 A	0.4 A	0.9 A	0.2 X	0.5 A
Lead Disks...	Blanks	0.5- 0.5	0.2- 0.2	0.5- 0.5	0.2- 0.2	0.1- 0.1	0.2- 0.3	0.1- 0.2	0.3- 0.3	0.1- 0.1
	Average	0.5	0.2	0.5	0.2	0.1	0.2	0.1	0.3	0.1
	Aluminum	0.4 X	0.2 X	0.4 X	0.2 X	0.2 X	0.2 X	0.2 X	0.3 X	0.2 X
	Zinc	1.5 A	0.4 A	0.5 X	0.2 X	0.1 X	0.2 X	0.1 X	0.2 X	0.2 X
	Tin	0.4 X	0.2 X	0.6 X	0.2 X	0.3 A	0.2 X	0.2 X	0.2 X	0.2 X
	Nickel	1.1 A	0.2 X	0.6 X	0.4 A	0.1 X	0.3 X	0.3 X	0.2 X	0.2 X
	Copper	1.5 A	0.2 X	0.6 X	0.2 X	0.2 X	0.2 X	0.2 X	0.2 X	0.2 X
	Iron	0.8 A	0.4 A	0.7 A	0.4 A	0.3 A	0.4 A	0.3 X	0.2 X	0.4 A
Tin Disks....	Blanks	0.3- 0.3	0.1- 0.1	0.2- 0.2	0.1- 0.1	0.1- 0.1	0.1- 0.1	0.1- 0.1	0-0	0-0
	Average	0.3	0.1	0.2	0.1	0.1	0.1	0.1		
	Aluminum	0.3 X	— X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X
	Zinc	0.2 X	0.1 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X
	Lead	0.3 X	0.1 X	0.1 X	0.2 X	0.1 X	0.0 X	0.1 X	0.0 X	0.0 X
	Nickel	1.1 A	0.2 X	0.1 X	0.1 X	0.1 X	0.0 X	0.1 X	0.0 X	0.0 X
	Copper	2.9 A	0.4 A	0.9 A	0.5 A	0.4 A	0.2 X	0.3 A	0.0 X	0.1 X
	Iron	2.8 A	0.5 A	1.3 A	0.4 A	0.3 A	0.2 X	0.2 X	0.1 X	0.1 X
Nickel Disks.	Blanks	0-0	0-0	0-0	0.2- 0.2	0.2- 0.2	0.1- 0.1	0.2- 0.2	0-0	0-0
	Average				0.2	0.2	0.1	0.2		
	Aluminum	0.0 X	0.1 X	0.0 X	0.1 X	0.1 X	0.0 X	0.1 X	0.0 X	0.0 X
	Zinc	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 X	0.0 P	0.0 X	0.0 X
	Lead	0.0 X	0.0 X	0.0 X	0.2 X	0.1 X	0.1 X	0.2 X	0.0 X	0.0 X
	Tin	0.0 X	0.0 X	0.0 X	0.2 X	0.2 X	0.1 X	0.2 X	0.0 X	0.0 X
	Copper	0.0 X	0.0 X	0.0 X	0.5 A	0.2 X	0.0 X	0.3 X	0.0 X	0.0 X
	Iron	0.2 A	0.1 X	0.0 X	0.3 X	0.1 X	0.0 X	0.2 X	0.0 X	0.0 X
Copper Disks	Blanks	0.9- 1.0	0.1- 0.1	0.1- 0.1	0.3- 0.3	0.2- 0.2	0.1- 0.1	0.2- 0.2	0-0	0-0
	Average	0.9	0.1	0.1	0.3	0.2	0.1	0.2		
	Aluminum	0.3 P	0.2 X	0.1 X	0.1 P	0.0 P	0.1 X	0.1 X	0.0 X	0.0 X
	Zinc	0.2 P	0.1 X	0.1 X	0.0 P	0.0 P	0.0 X	0.1 X	0.0 X	0.0 X
	Lead	0.3 P	0.0 X	0.1 X	0.3 X	0.2 X	0.1 X	0.2 X	0.0 X	0.0 X
	Tin	0.1 P	0.1 X	0.1 X	0.3 X	0.2 X	0.1 X	0.1 X	0.0 X	0.0 X
	Nickel	2.9 A	0.1 X	0.1 X	0.0 P	0.1 X	0.1 X	0.1 X	0.0 X	0.0 X
	Iron	0.8 X	0.2 X	0.1 X	0.3 X	0.1 X	0.1 X	0.1 X	0.0 X	0.1 X
Iron Disks...	Blanks	21.0-25.1	4.1- 4.0	3.5- 3.9	6.1- 5.7	3.9- 3.6	4.0- 3.5	4.9- 4.8	0.4- 0.3	1.6- 1.5
	Average	23.0	4.0	3.7	5.9	3.7	3.7	4.8	0.3	1.5
	Aluminum	9.8 P	4.7 A	2.4 P	3.3 P	3.1 P	2.5 P	6.1 A	0.3 X	1.4 X
	Zinc	3.9 P	0.1 P	0.1 P	0.2 P	0.1 P	0.0 P	0.0 P	0.0 P	0.5 P
	Lead	21.9 X	3.0 P	1.7 P	6.9 A	3.4 P	5.4 A	4.9 X	0.3 X	1.0 P
	Tin	18.4 P	4.0 X	2.2 P	8.7 A	4.5 A	5.6 A	6.0 A	0.5 X	2.4 A
	Nickel	23.3 X	4.2 X	4.4 A	6.8 A	4.0 A	3.8 X	6.4 A	0.4 X	2.0 A
	Copper	33.3 A	5.1 A	6.4 A	10.2 A	5.3 A	3.4 X	6.5 A	0.3 X	1.7 A

[a] The aluminum-iron couples have been omitted because of the loss of the aluminum disks.

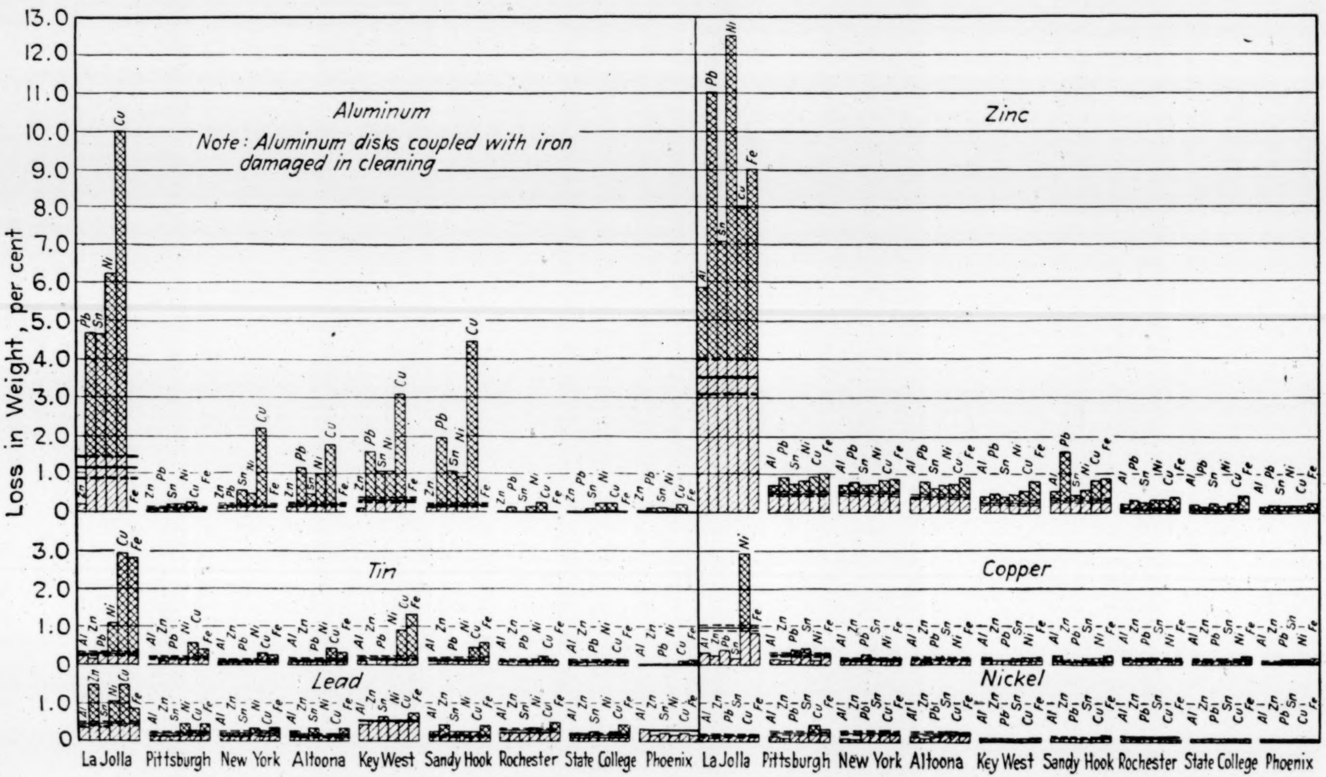

FIG. 1.—Galvanic Couple Corrosion: Percentage Loss in Weight of Aluminum, Tin, Lead, Zinc, Copper, and Nickel Disks After Three Years of Outdoor Exposure.

The heavy solid line through a group represents the average percentage weight loss of the two disks of the same metal coupled together as a blank. The heavy dotted lines indicate the percentage loss of weight of the individual disks in the blanks. The percentage loss in weight of the blank is a measure of the normal corrosion rate of this form of specimen of the metal in the respective test exposures. The double cross-hatching is used to indicate cases where the amount of corrosion of the disk was greater than the weight loss of the higher blank.

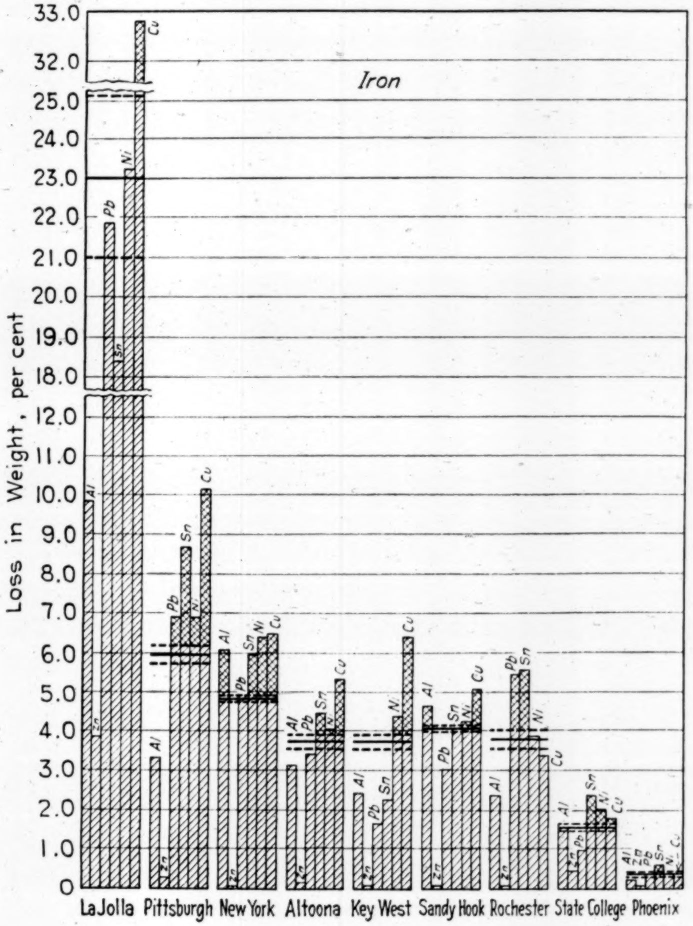

FIG. 2.—Galvanic Couple Corrosion: Percentage Loss in Weight of Iron Disks After Three Years of Outdoor Exposure.

DISCUSSION OF RESULTS

An effort has been made to present the data in a convenient form to facilitate an interpretation of the results and the formulation of such conclusions as seem justified. In drawing conclusions, due consideration must be given to all of the several factors involved and tolerance allowances made for such limitations and chance variations as are inherent to the conditions of test. In utilizing these data it should be borne in mind that they apply only to atmospheric exposure.

It is apparent from an inspection of the 3-yr. data that changes of sufficient magnitude have developed in several cases to justify tentative conclusions relative to the behavior of some of the metals when in contact with other metals at particular exposures. In most instances, the 3-yr. data, when compared with the 1-yr. results, show a consistent behavior for specific metals in a given type of exposure, while in a few cases there are minor inconsistencies which are probably within the chance variables of the test. In many instances the weight changes have been too small to be of significance except as an indication of relative corrosion at the respective exposures. The data on a very few couples of the same metal (blanks) show a substantial deviation in the weight changes for individual disks. It is not felt that indicated acceleration or protection of these metals, when coupled to other metals, has any important significance when the indicated difference is less than the deviation in the blanks. The symbols given in Table II indicate whether the corrosion of the metal listed in the first column is retarded or accelerated when coupled with the metals in the second column.

TABLE III.—GALVANIC COUPLE TEST, 3-YR. EXPOSURE COUPLE ACTION UNDER TYPICAL ATMOSPHERIC CONDITIONS.

Severe Marine[a]			Marine			Industrial			Rural		
Negligible[b]	Small[c]	Considerable[d]	Negligible[b]	Small[c]	Considerable[d]	Negligible[b]	Small[c]	Considerable[d]	Negligible[b]	Small[c]	Considerable[d]
		Al*-Cu	Al-Zn	Al*-Sn	Al*-Cu	Al-Sn	Al*-Cu		Al-Cu		
	Al-Zn*	Al*-Sn		Al*-Ni		Al-Zn	Al*-Ni		Al-Sn		
		Al*-Ni		Al*-Pb		Al-Pb			Al-Zn		
		Al*-Pb	Cu-Zn	Cu-Sn*	Cu-Fe*	Cu-Sn		Cu-Fe*	Al-Ni		
		Cu-Fe*	Cu-Ni			Cu-Zn			Al-Pb		
		Cu-Sn*	Cu-Pb			Cu-Ni			Cu-Fe		
		Cu-Zn*	Fe-Zn	Fe-Sn*		Cu-Pb			Cu-Sn		
Cu-Pb	Cu*-Ni		Fe-Ni			Fe-Zn	Fe*-Ni	Fe*-Sn	Cu-Zn		
Fe-Ni	Fe-Sn*	Fe-Zn*	Fe-Pb				Fe*-Pb		Cu-Ni		
Fe-Pb			Sn-Zn			Sn-Zn			Cu-Pb		
Sn-Ni		Sn-Zn*	Sn-Ni			Sn-Ni			Fe-Zn	Fe*-Sn	
Sn-Pb			Sn-Pb			Sn-Pb			Fe-Ni		
		Zn*-Ni	Zn-Ni	Zn*-Pb		Zn-Ni			Fe-Pb		
Ni-Pb		Zn*-Pb	Ni-Pb			Zn-Pb			Sn-Zn		
						Ni-Pb			Sn-Ni		
									Sn-Pb		
									Zn-Ni		
									Zn-Pb		
									Ni-Pb		

[a] Severe marine condition at La Jolla, Cal.
[b] Couple action negligible.
[c] Couple action not important but of sufficient magnitude to indicate a trend.
[d] Corrosion considerably accelerated on one or both disks of the couple.
* Indicates the metal on which corrosion is greatest. The magnitudes are shown in Figs. 1 and 2.
NOTE.—The aluminum-iron couples have been omitted because of the loss of the aluminum disks.

In Table III an effort has been made to group the couples with respect to the degree the couple action has accelerated the corrosion of one or both metals in the couple; that is, the table is prepared on the basis that if either metal is seriously effected by couple action the couple is an undesirable one.

It should be borne in mind, however, that the sacrificial corrosion of one metal in a couple to protect another is sometimes utilized to an advantage as in the case of protective metallic coatings, that is, zinc coatings on iron or steel.

CORRECTION OF 1934 REPORT

The following errors have been discovered in the 1934 report:

In Table I, the weight losses of the mild steel blank disks at La Jolla should read 1114 and 1150 mg. instead of 114 and 150 mg. In Fig. 3 the position of the heavy black line indicating the average percentage loss of the iron blanks at La Jolla should be at 8.8 per cent instead of 1.0 per cent.

Respectfully submitted on behalf of the subcommittee,

C. L. HIPPENSTEEL,
Chairman.

L. J. GORMAN,
Secretary.

REPORT OF COMMITTEE B-4

ON

ELECTRICAL-HEATING, ELECTRICAL-RESISTANCE AND ELECTRIC-FURNACE ALLOYS

Two meetings of Committee B-4 were held in New York City on October 15 and 16, 1934, and March 11 and 12, 1935, in addition to the meeting held during the annual meeting of the Society.

The present membership of the committee is 30, of whom 15 are classified as producers, 12 as consumers and 3 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS

Proposed Revision of Tentative Standard.—The committee recommends that the procedure for the application of thermocouples as specified in Section 7 (*b*) of the Tentative Method of Test for Linear Expansion of Metals (B 95 – 34 T),[1] be changed from its present form: namely,

> (*b*) *Calibrated Base-Metal or Platinum-Rhodium Thermocouples* and a calibrated high-grade industrial potentiometer may be used. Base-metal couples shall not be used for more than one cycle of heating and cooling at temperatures over 500 C. If platinum couples are used the portions near the specimen shall be cut off after operating for two runs at temperatures over 500 C.

to read as follows:

> (*b*) Nickel chromium - nickel aluminum (sold as Chromel-Alumel or Nichrome T-1—Nichrome T-2), nickel chromium - constantan (sold as Chromel-constantan or Nichrome T-1—constantan), iron-constantan, or platinum-rhodium thermocouples, in conjunction with a potentiometer, may be used. If the potentiometer is of the industrial type, it shall be calibrated and the scale corrections thus determined shall be applied. The cold junctions shall either be maintained at 0 C. by means of an ice bath or else the temperature determined by means of a liquid-in-glass thermometer placed very near them.
>
> (*c*) Iron-constantan or nickel chromium - constantan (sold as Chromel-constantan or Nichrome T-1—constantan) couples shall not be used for runs above 500 C. and nickel chromium - nickel aluminum (sold as Chromel-Alumel or Nichrome T-1—Nichrome T-2) couples for runs above 800 C. If base-metal couples are used they shall not be smaller than B. & S. gage No. 28 and shall be taken from coils of wire from which at least two other couples selected from different parts of the coil have been calibrated. Each sample shall be used for not more than two cycles of heating and cooling.
>
> (*d*) A platinum-rhodium couple shall be used above 800 C., protected by a porcelain tube to within a few millimeters of the hot junction The end of the couple

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 733 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 279.

shall be sealed through the end of the protection tube by pyrex glass (or a small amount of kaolin and water-glass cement) to prevent contamination of the couple, with the exception of a small length of 2 or 3 mm. near the hot junction which is attached to the specimen. After each cycle of heating and cooling, the seal shall be examined and if it is not in good condition, or if the projecting ends of the wires are brittle, this part of the wires shall be cut off and enough wire drawn through the seal to form a new junction.

The above recommendation has been submitted to letter ballot of the committee, which consists of 30 members; 27 members returned their ballots, of whom 19 have voted affirmatively, 0 negatively and 8 marked their ballots "not voting."

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Life Tests (J. W. Harsch, chairman).—Accelerated life tests are being made in several laboratories on a sample of 80 per cent nickel, 20 per cent chromium wire at temperatures of 1950, 2000 and 2050 F. (1065, 1095 and 1120 C.) to determine whether higher temperatures may be employed to expedite the test.

Subcommittee II on Electrical Tests (H. L. Curtis, chairman).—Further work has been done in the development of a standard method of test for temperature coefficient of sheet manganin. It has been necessary first to determine the conditions under which the test is to be made. Two important factors have been established during the year:

1. The method of attaching potential leads is not important. In one experiment, the leads were soft soldered to the manganin, and in the other they were attached to some "ears" cut from the manganin. The temperature-resistance curve was the same in both cases.

2. The method of pickling the sample before test is unimportant so long as all the surface layer of copper is removed. The problem of annealing the sample before test is now under investigation.

Subcommittee III on Chemical Analysis (T. R. Cunningham, chairman).—This subcommittee has recommended the formation of a standing committee on chemical analysis of metals and believes that the committee should give consideration to methods of analysis for both ferrous and non-ferrous alloys. Mr. Cunningham has been designated to represent Committee B-4 in this work.

Subcommittee IV on Mechanical Tests (P. H. Brace, chairman).—Two types of testing machines for determining the stiffness of electrical-resistance wires are being investigated. Both utilize a falling weighted pendulum. In one machine, the specimen is subjected to bending by impact, while in the other the weight is in contact with the specimen before the load is applied. Eight sizes of nickel wire have been tested to compare the two machines, with a view to the adoption of one machine as a standard. The machines will also be referred to the Sectional Committee on Specifications for Insulated Wires and Cables (Other than Telephone and Telegraph) functioning under the procedure of the American Standards Association for consideration in determining the stiffness of copper magnet wires.

Subcommittee V on Cast and Wrought Alloys for High-Temperature Use (C. L. Clark, chairman).—Some difficulty has been experienced in obtaining sound castings for the high-temperature tension test specimen. A new pattern is being made. The specimens will be examined with X-ray and will then be tested in four laboratories in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (E 21 – 34 T). A high-temperature bend test is also under consideration, especially for structural materials.

In order to determine their tendency to warp at elevated temperatures, several nickel-chromium alloys in the form of an eccentric tube are being tested at 1800 F. (980 C.).

As a test for structural stability, several alloys are being given a Charpy impact test before and after heating to 1800 F. (980 C.), and the grain size is also being determined.

Subcommittee VII on Thermostatic Metals (P. H. Brace, chairman).—In order to avoid confusion it was found necessary first to prepare a set of definitions for the various terms used. The name "thermoflex" has been adopted to designate the various materials which give useful flexure under the influence of temperature variations.

A program of tests is being carried on to determine the deflectivity, deflection stiffness and hardness of three materials, 0.025 in. and 0.050 in. in thickness, representing low, medium, and high-temperature service, respectively. The tests are being made in five laboratories—of which three are producer and two consumer. It has been necessary for several laboratories to build testing equipment and the committee has aided them in this development to secure the best results. Part of the test data has been secured and has been discussed in the committee.

This work requires a fundamental study of the subject as there are no standards in the industry. It is being carried on in cooperation with the Thermostatic Bimetal Manufacturers Association which has representation on Committee B-4 and Subcommittee VII.

This report has been submitted to letter ballot of the committee, which consists of 30 members; 22 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

DEAN HARVEY,
Chairman.

F. E. BASH,
Secretary.

REPORT OF COMMITTEE B-5

ON

COPPER AND COPPER ALLOYS, CAST AND WROUGHT

Committee B-5 on Copper and Copper Alloys, Cast and Wrought, held two meetings during the year, at Atlantic City, N. J., on June 28, 1934, and at Philadelphia, Pa., on March 5, 1935. Subsequent to its meeting last June, as noted in the 1934 annual report, Committee B-5 presented to the Society, through Committee E-10 on Standards, three new tentative specifications for copper-silicon alloys and tentative revisions of three standard specifications.[1] The new specifications and revisions were accepted as tentative by Committee E-10 and appear in the 1934 *Proceedings*.[2]

A paper being presented at this annual meeting of the Society by J. W. Bolton on "Some Tests on Tin Bronzes at Elevated Temperatures,"[3] discusses studies of alloys which are of interest to Committee B-5.

I. Proposed Tentative Standards.—At the March meeting of the committee the following three new specifications, which were prepared by Subcommittee I on Wrought Metals and Alloys (D. K. Crampton, chairman), were considered by the committee and approved for reference to letter ballot. The committee recommends that these specifications be accepted for publication as tentative, as appended hereto:

Tentative Specifications for Copper-Silicon Alloy Wire for General Purposes[4]

Tentative Specifications for Wrought Phosphor-Bronze Bearings and Expansion Plates for Bridges and Structures[5]

Tentative Specifications for Wrought Silicon-Bronze Bearings and Expansion Plates for Bridges and Structures[6]

The specifications providing standardized requirements for copper-silicon alloy wire were prepared as a result of a demand for a specification to cover material now being sold and used extensively for various structural purposes. The wire in question is well adapted to the making of bolts, screws, nails, rivets, springs, or other structural members requiring a material of high strength and high corrosion resistance. It was not possible to have these specifications in satisfactory form in time for inclusion with the specifications for copper-silicon alloy in other forms which were accepted for publication as tentative by Committee E-10 last August. Subcommittee I is now engaged in the preparation of other copper alloy wire specifications primarily intended for electrical purposes.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee B-5 reported the following results of the letter ballot vote of a total of 24 ballots returned from a committee membership of 49: on the three Tentative Specifications for Copper-Silicon Alloy, 17 affirmative, none negative and 7 ballots marked "not voting"; tentative revision of Standard Specifications for Steam or Valve Bronze Sand Castings (B 61 – 28), 19 affirmative, 1 negative and 4 ballots marked "not voting;" revision of Standard Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 – 28) and for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (B 60 – 28), 20 affirmative, none negative and 4 ballots marked "not voting;" withdrawal of Standard Specifications for the Alloy: Copper 88 per cent; Tin 10 per cent; Zinc 2 per cent (B 10 – 18), 20 affirmative, 1 negative and 3 ballots marked "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 249 (1934); also pp. 692 to 702, 1259 (1934).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 35, Part II, p. 204 (1935).

[4] See p. 750.

[5] These specifications were accepted as tentative and subsequent to the annual meeting Committee B-5 presented to the Society on August 22, 1935, through Committee E-10 on Standards a proposed revision of the tentative specifications. This revision was accepted by Committee E-10 and the specifications in their revised form appear on p. 732.

[6] At the annual meeting these specifications were referred back to Committee B-5 for further consideration, see Summary of Proceedings, p. 23.—Ed.

The specifications covering alloys for bearings and expansion plates for bridges were prepared to satisfy a continuing demand for guidance in the use of wrought metal as an alternative to the cast metal hitherto specified in this field as covered by the Standard Specifications for Bronze Bearing Metals for Turntables and Movable Railroad Bridges (B 22 - 21). The committee has under consideration the combination of these specifications.

II. Specifications Continued as Tentative.—The following specifications which have been tentative for a period of three years will be continued in this form for another year in view of the general program of comparative studies of all casting specifications now under way in Subcommittee II on Cast Metals and Alloys (G. H. Clamer, chairman):

Tentative Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (B 30 - 32 T)

Tentative Specifications for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent (B 74 - 32 T)

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 54 members; 31 members returned their ballots, the results being as follows:

Items	Affirm-ative	Neg-ative	Ballots Marked "Not Voting"
PROPOSED TENTATIVE STANDARDS			
Specifications for Copper-Silicon Alloy Wire for General Purposes	20	2	9
Specifications for Wrought Phosphor-Bronze Bearings and Expansion Plates for Bridges and Structures	22	0	9
Specifications for Wrought Silicon-Bronze Bearings and Expansion Plates for Bridges and Structures	22	0	9

This report has been submitted to letter ballot of the committee which consists of 54 members; 40 members returned their ballots, of whom 36 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

C. H. MATHEWSON,
Chairman.

D. K. CRAMPTON,
Secretary.

REPORT OF COMMITTEE B-6

ON

DIE-CAST METALS AND ALLOYS

Committee B-6 on Die-Cast Metals and Alloys has held two meetings during the year, one at Atlantic City, N. J., on June 29, 1934, and one at Philadelphia, Pa., on March 6, 1935, with an attendance of about 35 at each meeting. Certain of the subcommittees have held meetings at various times during the year. The resignation of Mr. C. R. Maxon from the committee has been accepted and Mr. W. W. Broughton, representing the New Jersey Zinc Co., has been elected to fill his place. At the present time the committee consists of 53 members, of whom 19 are classified as producers, 19 as consumers and 15 as general interests.

Mr. J. C. Fox has been appointed to represent Committee B-6 on the Joint Committee on Exposure Tests of Plated Coatings consisting of representatives of the National Bureau of Standards, the American Electro-Platers' Society and the A.S.T.M.

Mr. H. A. Anderson has been appointed chairman of a subcommittee consisting of Messrs. D. L. Colwell, J. A. Gann, C. E. Heussner, E. H. Dix, Jr., W. M. Peirce, J. R. Freeman, Jr., and J. R. Townsend to prepare an exhibit of the work of Committee B-6 for the Detroit meeting. This committee is responsible for the assembling of the material and the proper presentation of the exhibit at the annual meeting.

Mr. Sam Tour, chairman of Committee B-7 on Light Metals and Alloys, Cast and Wrought, has presented to Committee B-6 a tentative draft of Specifications for Aluminum Die-Casting Alloys in Ingot Form. This draft has been submitted to Committee B-6 for comment before further consideration by Committee B-7 at its June meeting.

A special committee has been appointed consisting of the Advisory Committee of Committee B-6 plus other members to be added by the Advisory Committee to constitute a committee to act as a clearing house for discovering causes of contamination of die castings so that the industry, in general, would be kept advised of any such findings.

RECOMMENDATIONS AFFECTING STANDARDS

Proposed Tentative Specifications.—The committee recommends that the proposed Tentative Specifications for Lead and Tin-Base Alloy Die Castings[1] be accepted for publication as tentative. This recommendation has been submitted to letter ballot of the committee which consists of 64 members; 37 members returned their ballots, of whom 22 have voted affirmatively, none negatively, and 15 marked their ballots "not voting."

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[1] See p. 753.

Specifications Continued as Tentative.—The committee recommends that the Tentative Specifications for Aluminum-Base Alloy Die Castings (B 85 – 33 T) and the Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 – 34 T) be continued as tentative without revision. The question of revision of these two specifications is now under active discussion by the respective subcommittees with the likelihood that some revisions may be prepared during the coming year.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Aluminum Base Die-Casting Alloys (E. E. Thum, chairman).—On the basis of the experimental work in the Research Laboratory of the Aluminum Company of America the subcommittee has undertaken a study of aluminum alloys Nos. IV and V corresponding to these grades in the Tentative Specifications for Aluminum-Base Alloy Die Castings (B 85 – 33 T) but of higher purity and with narrower composition ranges. The results of this work to date are reported in Appendix I.

Subcommittee II on Zinc Base Die-Casting Alloys (C. E. Heussner, chairman).—Mr. C. E. Heussner has been appointed chairman of this subcommittee since Vice Chairman W. H. Graves resigned from the chairmanship of Subcommittee II.

Subsequent to the 1934 annual meeting on the recommendation of this subcommittee, Committee B-6 presented to the Society through Committee E-10 on Standards a revision of the aluminum content of zinc-base alloy No. XXIII as covered by the Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 – 33 T). This revision consisted in changing the maximum aluminum content from "4.5 per cent" to "4.3 per cent." The revision was accepted[1] by Committee E-10 at a meeting held on August 22, 1934, and the specifications in their revised form appear in the 1934 *Proceedings*.[2]

Subcommittee III on Tin and Lead-Base Die-Casting Alloys (G. O. Hiers, chairman).—This subcommittee held two meetings during the year and has prepared proposed Tentative Specifications for Lead and Tin-Base Alloy Die Castings which are recommended for publication as tentative.[3] Supplementary methods of analysis for iron, zinc and aluminum in this type of alloy have been submitted to Committee E-3 on Chemical Analysis of Metals for their consideration.

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[1] In submitting this revision to Committee E-10 on Standards, Committee B-6 reported results of the letter ballot vote as follows: Of a total membership of 65, 44 members returned their ballots, of whom 37 voted affirmatively, 0 negatively, and 7 marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 706 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 252.

[3] See p. 753.

Subcommittee IV on Physical Tests of Die Castings (R. L. Templin, chairman).—The chairman reports that consideration has been given to the Monotron hardness tests of die castings, but as yet no work has been done along this line. There is work in progress in several laboratories on the fatigue testing of die castings, although the data are not yet available. A form of test specimen similar to that used on the R. R. Moore type of rotating-beam machine has been worked out. Some tests are also under way with a flat type of specimen. With the rotating-beam type of specimen it was found necessary to grind and polish the surface of the specimen and to machine the ends to insure that they were concentric with the reduced section. The problem of providing a flat type die-casting specimen is practically solved and since it is desirable to test material having a surface as cast, this work is being carried out on such specimens.

Subcommittee V on Exposure and Corrosion Tests (W. M. Peirce, chairman).—This subcommittee has completed the testing of the specimens from the 5-yr. indoor and outdoor corrosion racks, covering both zinc and aluminum alloys. The report of these tests appears as Appendix II. The tables in this report show the alloy, the exposure location, type of specimen, and test results comprising the tensile strength, elongation and impact strength.

Subcommittee VI on Finishing Properties of Die Castings (J. C. Fox, chairman).—The chairman of this subcommittee has under preparation a paper on the subject of finishing of die castings which will be available next year.

Subcommittee VII on Magnesium-Base Die-Casting Alloys (J. A. Gann, chairman).—This subcommittee recommends that the Tentative Specifications for Magnesium-Base Alloy Die Castings (B 94 – 34 T) be continued as tentative.

This report has been submitted to letter ballot of the committee which consists of 64 members; 34 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. R. TOWNSEND,
Chairman.

P. V. FARAGHER,
Secretary.

APPENDIX I

AN INVESTIGATION OF ALUMINUM DIE-CASTING ALLOYS Nos. IVa AND Va

At a meeting of Committee B-6 on February 21, 1934, data and exhibits were presented which illustrated that an improved aluminum die-casting alloy of the 12 per cent silicon type could be produced if certain limitations were incorporated in the present specifications.[1] Subcommittee I was requested to investigate the controlled-purity grades of the 5 per cent silicon (No. IV) and 12 per cent silicon (No. V) alloys, to be designated, respectively, as alloys Nos. IVa and Va. Alloy No. V, of a composition typical of the present specifications, was to be included in the tests as a control material. A subgroup consisting of H. A. Anderson, D. Basch, E. H. Dix, Jr., C. L. Hippensteel, and G. M. Rollason was appointed to plan and conduct the tests.

The purpose of this report is to record briefly the activities incident to the planning, preparation for, and initiation of the tests and to report data covering the analyses and original mechanical properties of the alloys being studied. All tests are now in progress. Subsequent reports will cover the accelerated or the atmospheric corrosion tests.

Plans for the Investigation:

Briefly, the plans for the test proposed that the General Electric Co. and the Aluminum Company of America, who had volunteered to produce the required specimens, each supply 350 standard round and 80 standard flat die-cast specimens of each of the three alloys. Duplicate sets of five specimens each were then to be used for original mechanical property determinations, exposures to the $3\frac{1}{2}$ per cent salt spray for three periods[2] at two laboratories, similar exposures[2] by alternate immersion in a $3\frac{1}{2}$ per cent sea-salt solution, and atmospheric exposures at three of the Society's exposure stations. The Western Electric Co. and the Aluminum Research Laboratories offered to make the necessary tests, while the Bell Telephone Laboratories agreed to conduct, as representatives of the Western Electric Co., half of the salt-spray tests.

Preparation of Specimens:

In accordance with the plans, the two producers cast the required specimens of each alloy, from compounded ingot metal supplied by the

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[1] Tentative Specifications for Aluminum-Base Alloy Die Castings (B 85 – 33 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 641 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 247.

[2] 12 weeks, 26 weeks and 1 yr.

Aluminum Company of America, and shipped them to the Aluminum Research Laboratories. The reported casting dates are included in Table III. The specimens were then stencilled with the assigned alloy identification number and a specimen serial number and were assembled in packs of five (each pack containing five bars with consecutive serial numbers). Table I gives the distribution of specimens among the several tests. In some cases, notably for the salt-spray tests, more "blanks" were set aside than it was considered would probably be required, in order to take care of possible contingencies. Those groups probably will not be tested and are omitted from the table.

TABLE I.—IDENTIFICATION OF MATERIALS AND DISTRIBUTION OF SPECIMENS IN TESTS.

IDENTIFICATION OF MATERIALS

Identification Number	Alloy	Producer
14865	No. IVa	Aluminum Company of America
14866	No. Va	Aluminum Company of America
14867	No. V	Aluminum Company of America
15431	No. IVa	General Electric Co.
15432	No. Va	General Electric Co.
15433	No. V	General Electric Co.

DISTRIBUTION OF SPECIMENS IN TESTS

Specimen Number	Test	Tested by[a]
1-5	Original properties	A
311-315	Original properties	A
6-10	Original properties	W
11-15	Blanks—12 weeks salt spray	A
16-20	Blanks—12 weeks salt spray	A
21-25	12 weeks salt spray at A	A
26-30	12 weeks salt spray at A	B
31-35	Blanks—12 weeks salt spray	B
41-45	12 weeks salt spray at B	A
46-50	12 weeks salt spray at B	B
51-55	Blanks—26 weeks salt spray	A
61-65	26 weeks salt spray at A	A
66-70	26 weeks salt spray at A	B
71-75	Blanks—26 weeks salt spray	B
81-85	26 weeks salt spray at B	A
86-90	26 weeks salt spray at B	B
101-105	1 year salt spray at A	A
106-110	1 year salt spray at A	B
111-115	Blanks—1 year salt spray	B
121-125	1 year salt spray at B	A
126-130	1 year salt spray at B	B
131-135	Blanks—12 weeks alternate immersion	A
136-140	Blanks—12 weeks alternate immersion	W
141-145	12 weeks alternate immersion	A
146-150	12 weeks alternate immersion	W
151-155	Blanks—26 weeks alternate immersion	A
156-160	Blanks—26 weeks alternate immersion	W
161-165	26 weeks alternate immersion	A
166-170	26 weeks alternate immersion	W
171-175	Blanks—1 year salt spray and alternate immersion	A
176-180	Blanks—1 year alternate immersion	W
181-185	1 year alternate immersion	A
186-190	1 year alternate immersion	W
191-195	Blanks—5 yr. atmospheric	A
231-235	Blanks—10 yr. atmospheric	A
271-275	Blanks—indefinite atmospheric	A
196-200	Blanks—5 yr. atmospheric	W
236-240	Blanks—10 yr. atmospheric	W
276-280	Blanks—Indefinite atmospheric	W
201-205	Sandy Hook—5 yr	A
206-210	Sandy Hook—5 yr	W
241-245	Sandy Hook—10 yr	A
246-250	Sandy Hook—10 yr	W
281-285	Sandy Hook—Indefinite	A
286-290	Sandy Hook—Indefinite	W
211-215	New York—5 yr	A
216-220	New York—5 yr	W
251-255	New York—10 yr	A
256-260	New York—10 yr	W
291-295	New York—Indefinite	A
296-300	New York—Indefinite	W
221-225	Altoona—5 yr	A
226-230	Altoona—5 yr	W
261-265	Altoona—10 yr	A
266-270	Altoona—10 yr	W
301-305	Altoona—Indefinite	A
306-310	Altoona—Indefinite	W
	Flat Specimens	
1-5	Original properties	A
6-10	Original properties	W
11-20	Sandy Hook (microscopic examination)	A & W
31-40	New York (microscopic examination)	A & W
51-60	Altoona (microscopic examination)	A & W

[a] A = Aluminum Research Laboratories, B = Bell Telephone Laboratories, W = Western Electric Co., Hawthorne Plant.

Chemical Analyses:

Five round and two flat tension specimens of each alloy as made by each producer were selected at random from the lots received (except No.

TABLE II.—CHEMICAL ANALYSES OF MATERIALS.

Identification Number	Alloy	Silicon, per cent	Iron, per cent	Copper, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Nickel, per cent	Tin, per cent	Lead, per cent	Aluminum, per cent
ROUND SPECIMENS[a]											
14865	No. IVa	4.72	1.06	0.10	0.01	0.01	0.00	0.01	0.00	0.00	balance
15431	No. IVa	4.78	1.11	0.10	0.02	0.01	0.00	0.01	0.00	0.00	balance
14866	No. Va	12.02	1.06	0.09	0.01	0.01	0.00	0.01	0.00	0.00	balance
15432	No. Va	11.87	1.34	0.09	0.01	0.00	0.00	0.01	0.00	0.00	balance
14867	No. V	12.18	1.37	0.42	0.25	0.05	0.51	0.31	0.05	0.02	balance
15433	No. V	12.09	1.51	0.42	0.26	0.06	0.52	0.32	0.05	0.03	balance
FLAT SPECIMENS[b]											
14865	No. IVa	4.75	1.07	0.09	0.01	0.01	0.00	0.01	0.00	0.00	balance
15431	No. IVa	4.67	1.09	0.10	0.02	0.00	0.00	0.01	0.00	0.00	balance
14866	No. Va	12.13	1.11	0.09	0.01	0.01	0.00	0.02	0.00	0.00	balance
15432	No. Va	11.91	1.22	0.09	0.01	0.00	0.00	0.01	0.00	0.00	balance
14867	No. V	12.16	1.40	0.42	0.24	0.05	0.51	0.31	0.05	0.03	balance
15433	No. V	12.01	1.51	0.42	0.26	0.06	0.52	0.32	0.05	0.03	balance
			max.	max.	max.	max.	max.	max.	max.	max.	
Nominal	No. IVa	5.0	1.5	0.15	0.1	0.05	0.20	0.10	0.05	0.05	balance
	No. Va	12.0	1.5	0.15	0.1	0.05	0.20	0.10	0.05	0.05	balance
	No. V	12.0	2.0	0.6	0.3	0.1	0.75	0.50	0.10	....	....

[a] Composite from 5 specimens.

[b] Composite from 2 specimens.

TABLE III.—ORIGINAL MECHANICAL PROPERTIES.

Identification Number	Alloy	Tested by[a]	Tensile Strength, lb. per sq. in.		Yield Strength, lb. per sq. in.[b]	Elongation in 2 in., per cent		Specimen	
			Strength	Standard Deviation		Elongation	Standard Deviation	Cast	Shape
14865	No. IVa	A	26 445	985	9 850	5.7	0.7	June 6, 1934	round[c]
			21 140	950	11 650	3.0	0		flat
		W	28 260	1250		6.1[d]	1.0		round
			20 070	820		....	....		flat
15431		A	25 600	940	11 950	4.8[e]	0.7	June 28, 1934	round
			25 830	505	12 400	4.6	0.4		flat
		W	25 140	1370		4.8[f]	0.6		round
			25 940	530		5.0[g]	0		flat
14866	No. Va	A	32 200	1575	16 450	2.3[h]	0.34	June 5, 1934	round
			36 525	2910	20 000	2.3	0.9		flat
		W	32 420	1670		2.1[d]	0.4		round
			33 120	4640		4.0[g]	0		flat
15432		A	27 555	1775	17 325	1.2[i]	0.2	June 25, 1934	round
			29 340	1670	18 300	1.6[i]	0.5		flat
		W	30 900	1555		2.0	0.3		round
			29 360	2295		1.5[j]	0		flat
14867	No. V	A	34 630	2510	18 575	2.0	0.35	June 7, 1934	round
			34 450	2170	22 350	1.3[h]	0.4		flat
		W	38 080	1065		2.4[d]	0.2		round
			39 260	1795		2.0[f]	0		flat
15433		A	28 365	2440	18 850	1.1	0.3	June 16, 1934	round
			28 785	2685	19 150	1.2[e]	0.2		flat
		W	29 060	3255		1.5[d]	0.35		round
			28 380	2755		1.5[f]	0		flat

[a] A = Aluminum Research Laboratories, W = Western Electric Co., Hawthorne Plant.

[b] 0.2 per cent permanent set (determined by A only).

[c] Ten round specimens tested by laboratory A; five by W.

[d] Average of four specimens, others broke outside gage marks.

[e] One specimen broke outside gage marks but was included in average.

[f] Average of three specimens, others broke outside gage marks.

[g] Single specimen, others broke outside gage marks.

[h] Three specimens broke outside gage marks but were included in average.

[i] Two specimens broke outside gage marks but were included in average.

[j] Average of two specimens, others broke outside gage marks.

15431, round, where only four samples were taken) and submitted for chemical analysis.[1] The laboratory was instructed to make a composite sample from the round specimens and another from the flat specimens of each lot and report the analysis of each. The results, summarized in Table II, are believed to represent the typical compositions of the materials in test. These data illustrate the relative uniformity of materials of the same nominal composition, regardless of producer and shape of specimen, as well as the small amount of impurities in alloys Nos. IVa and Va. Since both producers used compounded ingot from the same source, contamination during casting would be the principal source of variations between the two suppliers' products. The uniformities in composition indicate relatively close plant control.

TABLE IV.—AVERAGE ORIGINAL MECHANICAL PROPERTIES.
(Regardless of Testing Variables.)

Identification Number	Alloy	Round Specimens		Flat Specimens	
		Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent
14865	No. IVa	27 050	5.8	20 605	3.0
15431		25 450	4.8	25 885	4.7
14866	No. Va	32 375	2.2	34 820	2.6
15432		28 670	1.4	29 350	1.6
14867	No. V	35 780	2.1	36 855	1.6
15433		28 595	1.2	28 580	1.3

TABLE V.—AVERAGE MECHANICAL PROPERTIES.
(Regardless of Casting or Testing Variables.)

Alloy	Round Specimens		Flat Specimens	
	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent
No. IVa	26 250	5.3	23 245	3.9
No. Va	30 525	1.8	32 085	2.1
No. V	32 190	1.7	32 720	1.5

Original Mechanical Properties:

Ten round and five flat tension specimens of each alloy as supplied by each producer were tested by the Aluminum Research Laboratories, while five round and five flat specimens of each group were tested by the Hawthorne Plant of the Western Electric Co. The average mechanical properties of the various groups as reported by the two testing laboratories are summarized in Table III. As is evident, these averages for a given producer's material are relatively uniform.

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[1] Analyses of these materials were made by only the Aluminum Research Laboratories.

Tables IV and V present these mechanical property data in slightly different forms. In the former, variations in the procedures of the two testing laboratories are not considered to exist, and the average properties of each producer's specimens of a given alloy are presented. In calculating these averages, consideration was given to the number of specimens tested by each laboratory so that for the round specimens the data represent an average of fifteen tests. In the latter table (Table V) the average mechanical properties of each alloy, regardless of the source or the tester, are presented.

It is interesting to note, from the data of Table V, that the average mechanical properties of the alloy No. V specimens in this investigation are essentially those which the Society suggests may be expected from this material (Tentative Specifications for Aluminum-Base Alloy Die Castings, B 85 – 33 T[1]) and that the shape of the specimen has had no effect. It is also of interest that the reduction of impurities in this alloy, although it might be expected to reduce slightly the tensile strength and increase the elongation, has exerted but little effect on the properties. The strength of alloy No. IVa is apparently slightly below the typical values for the less pure composition of alloy No. IV (B 85 – 33 T), but with a concurrent increase in elongation. It might be concluded then, that properties typical of the more impure compositions may be secured with alloy No. Va, but that the *average* strength of alloys Nos. IVa and Va will be somewhat less and the elongations somewhat greater than for alloys Nos. IV and V.

Comparison of the standard deviations for the high purity alloys with similar data for alloys Nos. IV and V of the committee's previous investigation leads to the conclusion that these newer alloys are not subject to greater variations in strength and elongation as a result of their purity (even though the higher purity material *may* be more prone to porosity).

Visual examination of the broken tension specimens by the two testing laboratories resulted in the following general observations:

Alloy No. IVa.—The round specimens from one producer (No. 14865) were uniformly quite sound but those from the other (No. 15431) were somewhat porous. The flat specimens, regardless of producer, were relatively porous but the one set (No. 15431) had this porosity chiefly near the center while in the other it more closely approached the surface.

Alloy No. Va.—In general, the round specimens of this alloy from one producer (No. 14866) were sound but those from the other (No. 15432) were in some cases markedly porous. The relatively low strength of material No. 15432 tested by the Aluminum Research Laboratories (Table III) is possibly the result of this porosity. The flat specimens of the alloy from one producer (No. 14866) were slightly less porous than those from the other, although both groups were reasonably sound.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 641 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 247.

Alloy No. V.—Here again the round specimens from one producer (No. 14867) were somewhat sounder than those from the other, the latter having as much as 20 per cent porosity. The flat specimens varied quite a little from one to the other, some being reasonably sound and a few markedly porous. Most of the porous specimens were from one producer (No. 15433).

Conclusions:

An inspection of the data included in this report leads to the following conclusions:

1. The experimental alloys Nos. IVa and Va made for this investigation were well within the specified composition limits and can apparently be commercially produced to these limits except in small castings, where the iron limit may be too low.

2. The specimens of a given alloy, regardless of shape or producer, are of very uniform composition, especially as regards the minor impurities; indicating that contamination during casting was avoided.

3. The average tensile strength of alloys Nos. IVa and Va, as supplied by a number of producers, will probably be about 5 to 10 per cent less than that of their lower-purity counterparts but the elongations will be slightly higher.

4. The shape of the tension specimen used to evaluate the properties of alloy No. Va will apparently have no effect but with alloy No. IVa may result in lower strengths when flat specimens are employed.

5. The flat specimens of alloy No. IVa appear somewhat more prone to porosity than do the round specimens.

6. Except for the flat specimens of alloy No. IVa, the specimens of alloys Nos. IVa and Va are generally no more porous than similarly shaped specimens of alloy No. V made by the same producer.

7. The specimens for this investigation made by one producer (Nos. 15431, 15432 and 15433) were generally more porous than those supplied by the other.

Respectfully submitted on behalf of Subcommittee I on Aluminum Base Die-Casting Alloys,

E. E. THUM,
Chairman.

APPENDIX II

REPORT OF SUBCOMMITTEE V ON EXPOSURE AND CORROSION TESTS

This report covers the results of the first five years of exposure tests of 12 aluminum and 10 zinc alloys cast by several producers and exposed at six outdoor and four indoor locations.

It was originally planned to test the outdoor exposure specimens after 1, 3 and 5 yr. exposure. Lack of testing facilities to test the 3-yr. outdoor specimens in 1932 led to the decision to test the outdoor specimens after the same aging periods as had been planned for the indoor specimens, namely 1, 5 and 10 yr.

The data obtained from the test bars, exposed both indoors and outdoors for 1 yr., were presented in 1932[1] but without comment since it was felt that the exposure was of too short duration to draw reliable conclusions. These data are presented graphically in the accompanying Figs. 1 and 2.

At the end of 4 yr. the outdoor exposure specimens were all photographed at the test locations without removing the corrosion products. Complete copies of this photographic record are in the files of the Chairman of Committee B-6 and of Subcommittee V. The tabulation given in the Appendix[2] to this report gives the general surface appearance of each alloy at each location.

The data on the 5-yr. specimens are now available and are presented in the accompanying tables. Results are reported on $\frac{1}{4}$-in. round tension and $\frac{1}{4}$ by $\frac{1}{4}$-in. square impact specimens. For the tension bars the results in general are averages of five specimens and for the impact bars the results are averages of ten tests determined on five bars each of the latter, being cut into two pieces 3 in. long prior to testing. In a great many cases the results are averages of a lesser number of specimens since some specimens were stolen from the racks at the exposure locations; broken or badly bent during shipment; or so badly warped during exposure that they could not be tested. Flat tension specimens exposed at the indoor locations were tested but since the tests were started, it has become evident that the round tension specimens give all the necessary information. The data for the 5-yr. specimens, covering both indoor and outdoor exposure, are presented graphically in Figs. 3 and 4. These may be compared with Figs. 1 and 2 covering the corresponding 1-yr. tests.

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[1] Appendix to Report of Committee B-6 on Die-Cast Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 271 (1932).

[2] See p. 214.

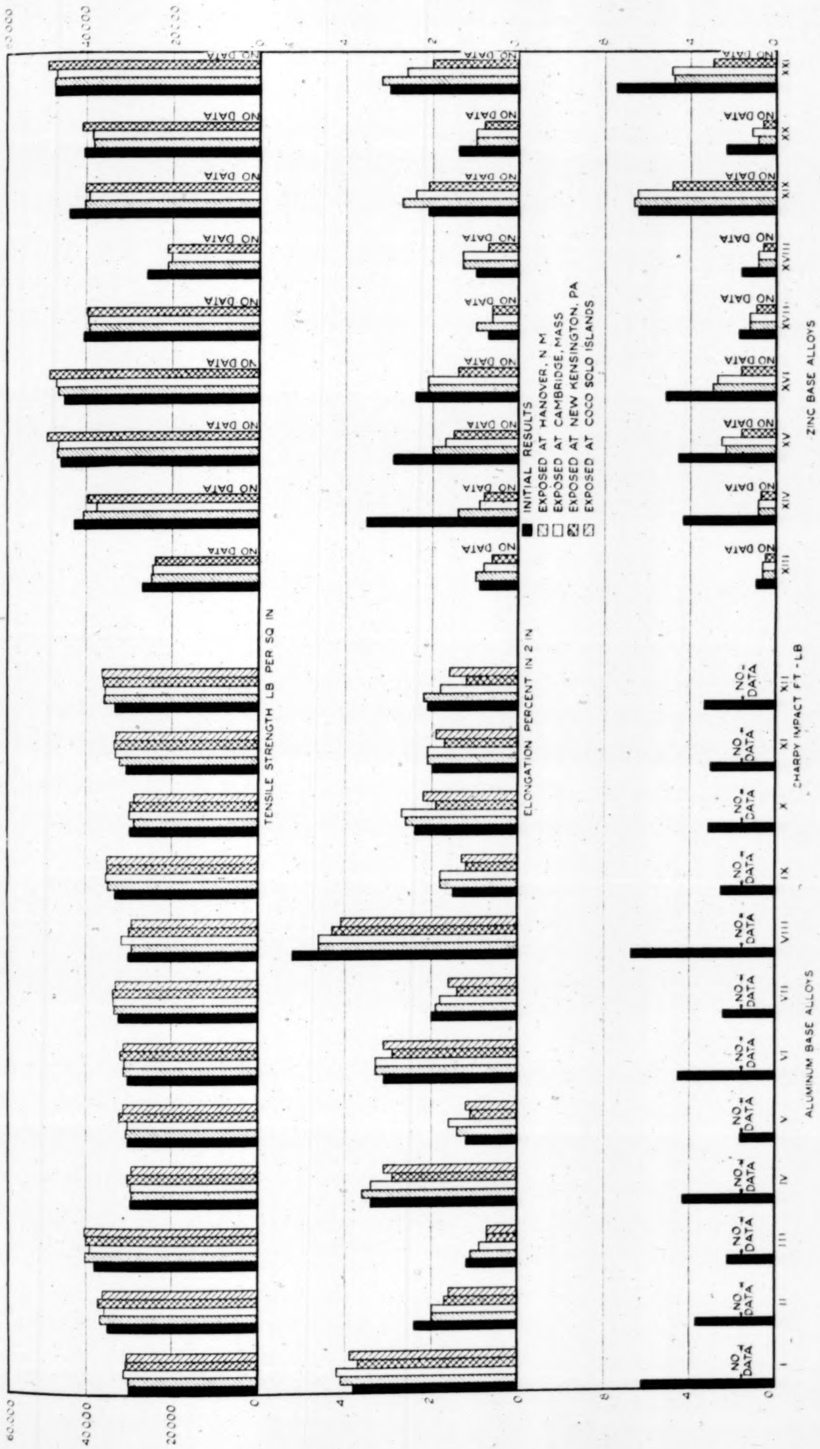

FIG. 1.—One-year Indoor Exposure.

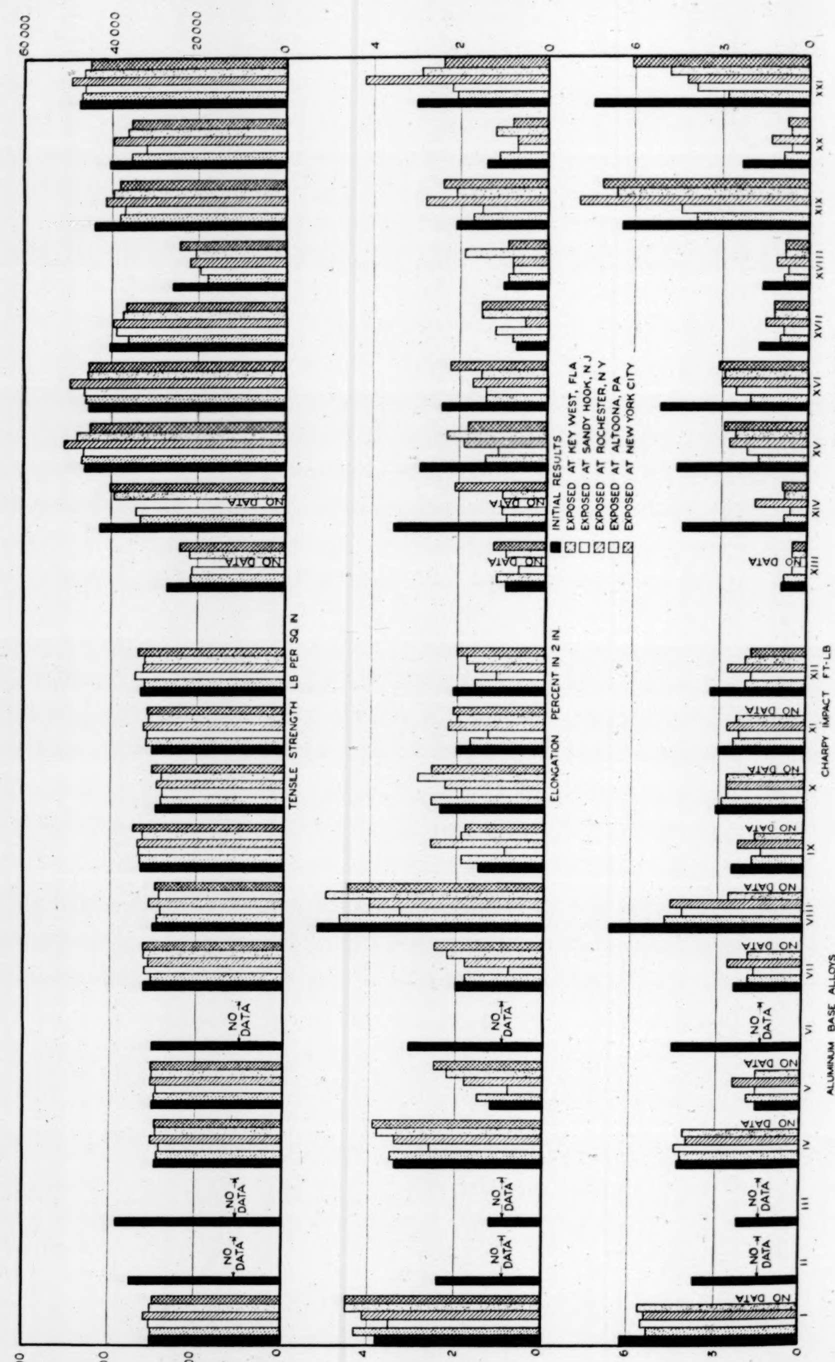

FIG. 2.—One-year Outdoor Exposure.

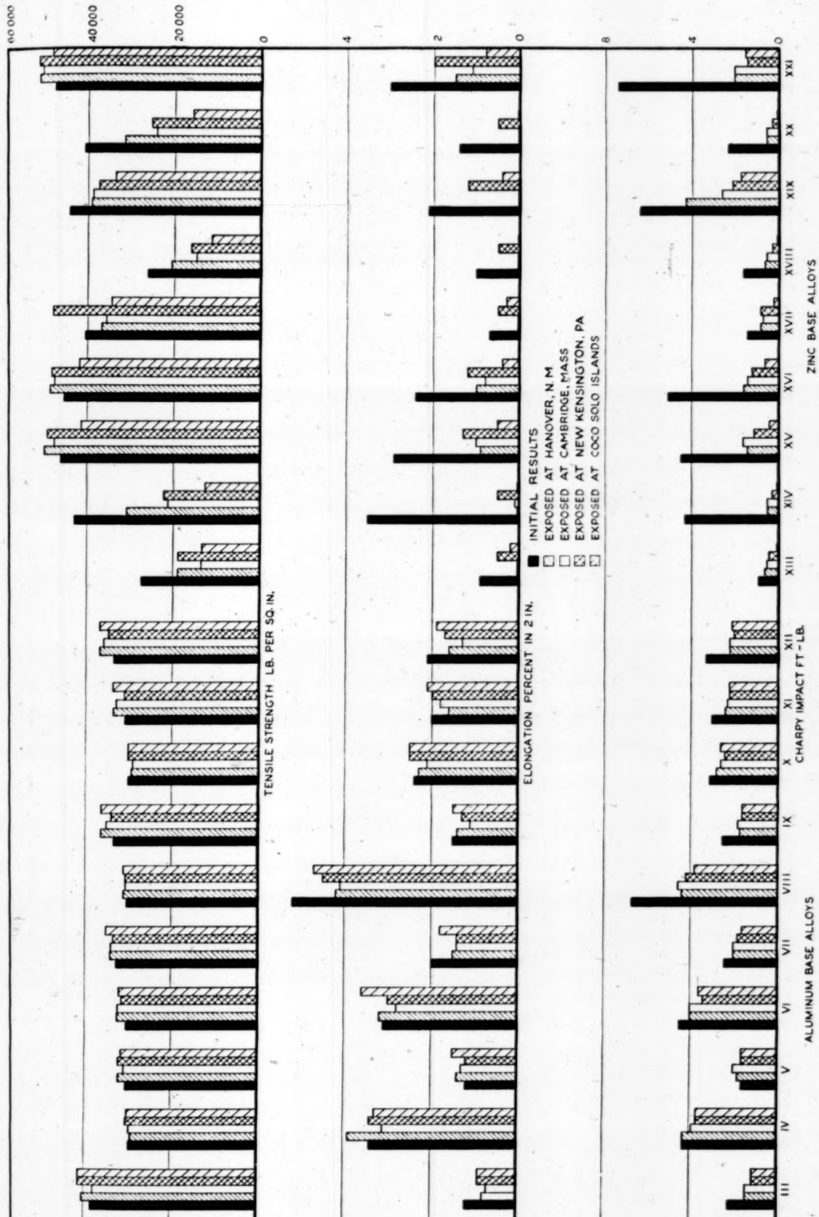

FIG. 3.—Five-year Indoor Exposure.

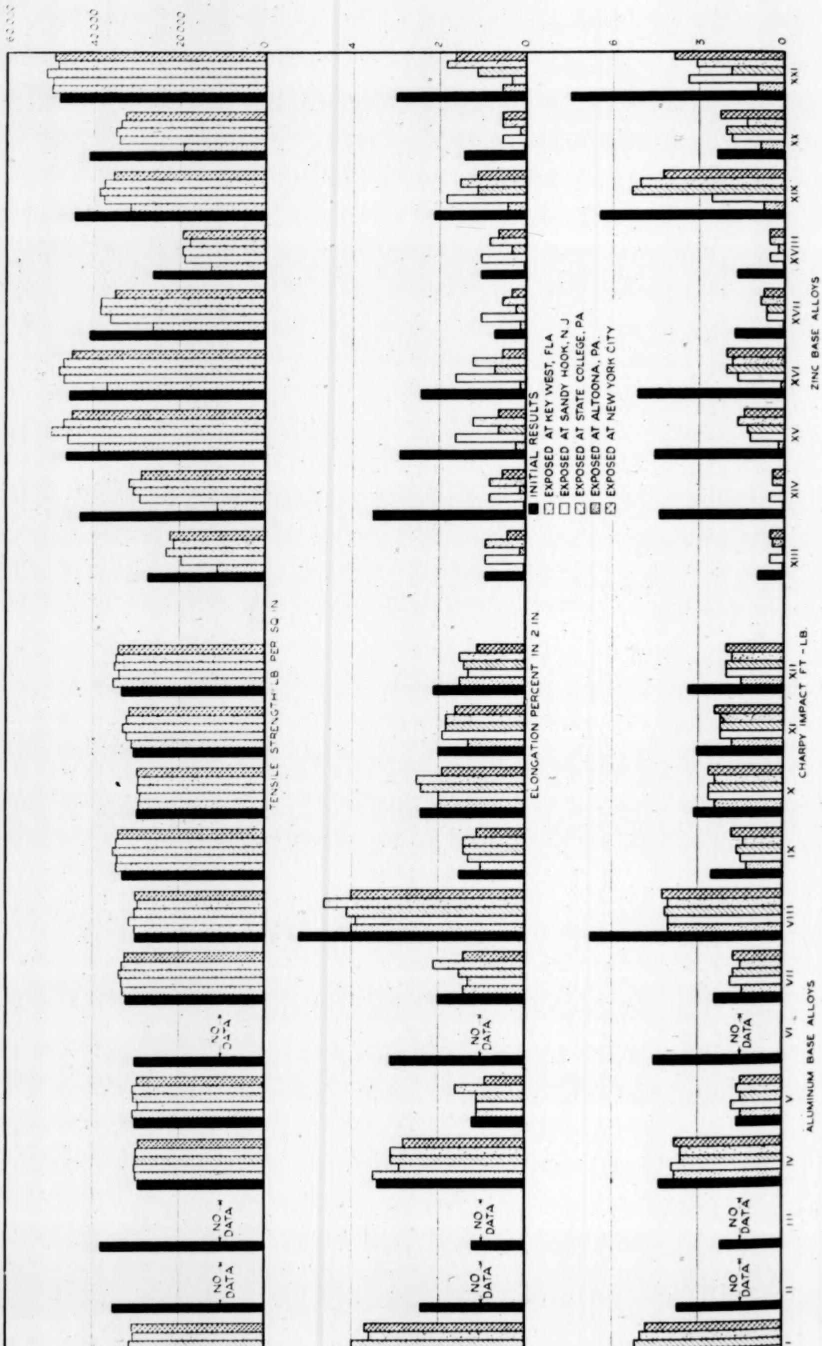

FIG. 4.—Five-year Outdoor Exposure.

The present report is divided into two parts. The first part relates to the discussion of the aluminum alloys, and the second, to the zinc alloys.

Part I—Aluminum Alloys:

Examination of the mechanical property data for the 12 aluminum alloys after an exposure of 1 and 5 yr. at the four indoor and five[1] of the six outdoor stations leads to the general conclusion that no significant changes have been induced by corrosion and only small changes have resulted from aging. In several instances, the data at their face value suggest measurable changes from one of the two causes but careful analysis usually will reveal that inherent variability among the test specimens probably is responsible.

In analyzing these data, the average properties of each producer's specimens of a given alloy at each of the nine stations were compared with the original properties reported for this producer's material. This procedure theoretically should result in isolating changes developed at the indoor stations as a result of aging and at the outdoor stations from aging plus corrosion. In order to separate aging from corrosion effects at the outdoor stations, the data from the latter were compared with the average properties developed after a similar period at the four indoor stations. Changes in properties indicated by these comparisons should theoretically be caused by corrosion. Similar comparisons were made for the average properties of each *alloy* at the several stations.

The term "theoretically" is believed to have been used advisedly in the preceding discussion, as there are a number of instances in which purely mathematical comparisons yield results not believed to be truly accurate. For instance, in the case of alloy No. I, producer D, the original properties reported are relatively low as compared with the properties for specimens made by other producers. After 5 yr. at several indoor stations, the properties of this alloy are more nearly in line with those for the other producers' materials, indicating a relatively large increase in tensile strength and elongation due to aging. In this, and similar cases where inconsistent data are encountered, conclusions must be predicated from a general consideration of specimens furnished by several or all of the five producers.

Age hardening of aluminum alloys is generally indicated in mechanical property data by an increase in tensile strength and a decrease in elongation and impact strength. Applying these criteria to the indoor data in comparison with the original properties leads to the conclusion that alloys Nos. I, II, III and XII probably have age hardened, that alloys Nos. VI, VII, IX and XI possibly have age hardened slightly and that alloys Nos. IV, V, VIII and X have developed no significant changes. It is interesting to note that the alloys which have probably age hardened contain either copper alone or in predominance; those that age harden slightly contain 2 to 4 per cent copper, together with other elements, and those which apparently do not age harden contain either no copper or only a small amount.

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[1] No data from State College at one year nor Rochester after five years.

Examination of the data for the indoor stations indicates that no apparent difference in aging has been encountered between the northern and southern stations. Probably this has resulted from the particular storage conditions in effect at the four stations. For instance, the specimens stored at New Kensington were located in a room (and at a location in that room) where the temperature was relatively uniform throughout the year and possibly never fell below about 60 F. (except for infrequent, short periods). With relatively small differences in the average temperature at the four indoor stations then, approximately uniform aging effects would be expected.

It may be pertinent to the discussion of "aging" effects to point out that the changes in elongation and impact strength indicate more general age hardening effects than are confirmed by the tensile strengths. The actual elongations and impact strengths being of relatively small order, however, leads to a magnification of the changes when expressed as a percentage of the original values, even though the actual change may be slight. In addition, testing was done by stations rather than alloys (a given testing laboratory had all specimens from one station), so that unavoidable variations in testing procedure or equipment may have introduced large percentage changes. Somewhat more weight has, therefore, been attached to tensile strength changes than to changes in elongation or impact strength.

Careful analyses of the mechanical properties of the specimens exposed for 5 yr. at the five outdoor stations lead to the general conclusion that any corrosion which may have developed was merely a surface attack having no definitely measurable effect on the mechanical properties; particularly in comparison with the 5-yr. indoor exposure data. Critical examination, and the assumption that variations in specimens or testing procedures had no effect, suggest that the alloys containing nickel (alloys Nos. VIII and IX) may have developed some pitting and that Key West is slightly more severe an exposure station than the others. (This latter observation is not very well in accord with data accumulated for wrought alloys by Subcommittee VI on Atmospheric Corrosion of Non-Ferrous Metals and Alloys[1] of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys).

The data from these 5-yr. exposures, even though they prove only that the aluminum alloys in the tests are mechanically unaffected by either corrosion or aging, are of practical value in allaying any possible fears

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[1] See p. 142.

ALLOY NO. I.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	4.0	......	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	4.37	0.43	nil	1.48	0.01	0.03	0.05	93.63	nil
Producer D	3.51	0.63	0.17	1.50	0.03	0.03	0.18	93.95	nil
Producer G	3.97	0.32	0.03	2.77	0.02	0.01	nil	92.80	Tin 0.08
Producer S	4.23	0.59	0.45	1.90	0.02	0.04	0.03	92.74	nil
Producer W	3.80	0.31	nil	2.25	0.03	nil	0.08	93.43	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. (1/4 IN. DIAMETER ROUND BARS)											
C	28 940	29 300	29 800	c	29 600	29 500	30 900	31 000	29 600	30 700	30 800
D	24 660	24 100	27 300	c	26 700	26 900	26 100	28 500	28 000	28 100	28 300
G	29 240	29 600	30 100	c	30 200	31 200	31 600	29 400	30 000	32 300	31 000
S	33 380	33 300	33 500	c	33 900	33 800	35 600	33 700	34 700	34 000	34 700
W	31 570	30 300	30 700	c	33 100	33 500	33 500	32 600	34 100	30 400	32 200
ELONGATION IN 2 IN., PER CENT (1/4 IN. DIAMETER ROUND BARS)											
C	4.8	4.2	4.2	c	3.8	3.3	4.8	4.1	3.8	3.9	4.2
D	2.8	3.1	3.9	c	3.5	3.5	3.6	3.6	3.2	3.3	....
G	2.8	3.0	3.4	c	2.5	3.2	2.9	3.1	2.7	3.0	2.9
S	4.4	4.1	3.8	c	4.0	3.8	4.6	4.6	2.6	4.5	4.0
W	3.6	3.8	3.6	c	4.3	3.7	4.0	4.0	3.6	2.4	1.7
CHARPY IMPACT VALUE, FT-LB. (1/4 IN. SQUARE BARS)[b]											
C	......	3.50	3.75	5.00[d]	4.25	4.50	4.50	4.25	3.75	4.00	4.50
D	......	4.00	5.75	5.25[d]	5.50	4.75	5.75	6.00	6.25	5.00	6.00
G	5.4	2.00	4.00	3.50[d]	3.50	4.50	4.50	5.00	4.00	3.75	4.50
S	7.5	4.75	6.00	5.50[d]	6.25	5.75	7.00	6.75	7.00	7.50	7.25
W	6.5	4.50	5.50	5.25[d]	5.75	4.50	4.25	5.00	5.25	4.50	6.25

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. II.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	10.0	......	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	7.13	0.38	nil	1.96	0.01	0.04	0.16	90.52	nil
Producer D	8.97	0.34	0.05	1.44	0.03	0.13	0.09	88.95	nil
Producer G	9.36	0.31	nil	1.71	0.02	nil	nil	88.60	nil
Producer S	10.47	0.44	nil	1.44	0.01	0.01	0.05	87.58	nil
Producer W	8.93	0.44	nil	3.07	0 03	nil	0.20	87.33	nil

Producer	As Cast	5-yr. Indoor Exposure				As Cast	5-yr. Indoor Exposure			
		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
	TENSILE STRENGTH, LB. PER SQ. IN. (1/4 IN. DIAMETER ROUND BARS)[c]					ELONGATION IN 2 IN., PER CENT (1/4 IN. DIAMETER ROUND BARS)[c]				
C	34 470	36 400	35 700	37 200	36 800	3.2	2.7	2.3	2.7	2.7
D	34 760	37 700	35 600	35 900	34 400	1.0	1.7	1.0	1.0	0.8
G	34 620	37 300	34 700	38 800	35 900	2.6	2.6	1.5	1.5	1.9
S	33 590	40 400	36 200	39 200	38 600	1.8	1.7	1.1	1.6	1.5
W	37 220	39 400	39 200	40 000	39 200	1.8	1.3	1.0	1.5	1.0
CHARPY IMPACT VALUE, FT-LB. (1/4 IN. SQUARE BARS)[b, c]										
C	4.0	2.75	3.75	2.50	3.50					
D	......	2.00	2.25	2.25	2.25					
G	4.1	3.00	3.25	2.75	3.00					
S	3.4	2.00	2.75	2.25	3.00					
W	2.6	1.75	2.00	1.75	2.00					

[a] By difference.

[b] Average of two tests on each specimen.

[c] This alloy not exposed outdoors.

ALLOY NO. III.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	14.0	......	......	1.5 to 2.0	0.05 max.	0.05 max.	.....	Remainder	......
Producer C	11.99	0.43	0.14	1.76	0.02	0.03	0.09	85.54	nil
Producer D	13.14	0.32	0.12	1.67	0.08	0.03	0.09	84.55	nil
Producer G	14.29	0.27	nil	1.72	0.02	0.01	0.03	83.68	nil
Producer S	13.20	0.53	nil	1.57	0.01	0.01	0.08	84.60	nil
Producer W	13.02	0.37	nil	2.74	0.03	0.02	0.11	83.71	nil

Producer	As Cast	5-yr. Indoor Exposure				As Cast	5-yr. Indoor Exposure			
		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
	TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)[c]					ELONGATION IN 2 IN., PER CENT (¼ IN. DIAMETER ROUND BARS)[c]				
C	37 480	41 700	40 900	40 300	41 700	1.5	0.7	1.3	1.4	1.1
D	38 020	40 800	40 700	41 200	40 100	0.5	1.1	0.5	0.9	0.6
G	35 890	39 600	39 100	39 400	37 200	2.7	1.0	0.5	0.5	0.8
S	40 230	42 300	42 300	43 100	43 400	1.0	1.0	0.9	0.9	0.5
W	40 180	42 900	41 000	43 400	39 700	1.0	0.8	0.5	0.9	0.8
	CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b,c]									
C	......	1.25	1.50	1.00	1.50					
D	......	1.00	1.25	1.00	1.50					
G	2.2	1.00	1.25	1.00	1.00					
S	2.4	1.25	1.50	1.25	1.75					
W	1.8	1.00	1.25	1.25	1.00					

[a] By difference.

[b] Average of two tests on each specimen.

[c] This alloy not exposed outdoors.

ALLOY NO. IV.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	......	5.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	0.58	4.16	0.01	1.85	0.01	0.07	0.02	93.30	nil
Producer D	0.34	5.07	nil	1.48	0.07	0.06	0.44	92.54	nil
Producer G	0.68	5.27	nil	1.29	0.02	0.01	nil	92.73	nil
Producer S	0.24	5.11	0.22	1.89	0.04	0.01	0.11	92.38	nil
Producer W	0.61	4.41	nil	2.53	0.05	0.02	5.90	86.50	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
	TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)										
C	30 160	31 500	30 500	c	30 100	30 600	32 000	31 500	30 000	31 700	31 200
D	25 680	27 000	25 200	c	28 000	25 400	26 000	24 300	25 400	25 800	26 200
G	29 600	31 000	30 100	c	30 000	29 700	31 000	31 000	29 500	31 400	30 500
S	29 610	29 700	31 600	c	29 700	31 500	31 900	31 200	30 900	31 400	30 400
W	30 150	31 000	34 400	c	33 100	30 300	30 300	32 000	32 400	32 200	27 500
	ELONGATION IN 2 IN., PER CENT (¼ IN. DIAMETER ROUND BARS)										
C	4.6	4.4	4.0	c	3.5	3.4	4.2	4.3	4.3	4.4	4.5
D	2.3	3.1	2.3	c	2.9	2.4	2.1	2.3	2.5	2.2	2.5
G	3.6	4.5	3.5	c	3.5	3.1	4.1	4.1	3.4	4.2	4.0
S	3.7	3.7	3.5	c	3.6	3.5	3.7	4.1	3.6	3.8	4.5
W	2.1	2.0	1.4	c	2.2	1.4	1.6	1.9	1.6	2.5	......
	CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b]										
C	4.3	3.50	4.25	4.50[d]	3.25	4.00	3.50	3.75	3.50	3.75	4.25
D	......	3.50	3.75	3.75[d]	3.25	3.50	3.50	3.50	4.00	3.75	4.25
G	5.7	4.00	4.25	4.25[d]	4.25	4.75	4.25	4.00	4.50	3.75	4.50
S	6.3	5.75	5.25	4.75[d]	5.25	4.75	5.00	5.25	5.50	5.25	6.00
W	2.6	2.00	2.00	2.50[d]	1.75	2.00	1.75	2.00	2.00	2.00	2.50

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. V.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	......	13.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	0.64	13.0	0.08	1.59	0.19	0.09	0.22	84.20	nil
Producer D	0.98	12.96	0.03	1.52	0.09	0.12	0.90	83.40	nil
Producer G	0.15	12.42	nil	1.89	0.03	0.01	0.03	85.20	Tin 0.06 Lead 0.21
Producer S	0.05	12.97	0.02	1.35	0.02	0.03	0.06	85.50	nil
Producer W	0.20	10.72	nil	4.34	0.06	0.04	0.60	84.04	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. (1/4 IN. DIAMETER ROUND BARS)											
C	34 090	34 700	32 000	[c]	31 600	32 400	34 400	35 300	33 600	34 100	35 100
D	25 810	27 400	29 000	[c]	[e]	27 000	27 700	28 600	30 100	27 000	27 300
G	28 480	29 600	26 000	[c]	28 100	25 400	26 200	31 300	29 300	32 000	29 700
S	34 650	36 900	35 400	[c]	34 500	34 800	34 800	34 700	34 000	37 400	37 800
W	28 120	25 800	25 800	[c]	28 200	28 900	29 000	26 800	27 100	29 300	30 200
ELONGATION IN 2 IN., PER CENT (1/4 IN. DIAMETER ROUND BARS)											
C	1.4	1.0	1.1	[c]	1.0	1.0	1.4	1.4	1.5	1.1	1.3
D	0.9	0.9	1.1	[c]	[e]	0.5	0.6	0.7	1.0	0.6	1.0
G	1.4	1.5	1.0	[c]	1.5	1.0	1.0	1.9	1.4	1.2	1.1
S	2.8	1.7	1.5	[c]	1.5	1.7	1.8	2.6	1.7	2.9	2.8
W	1.1	0.5	0.6	[c]	2.3	0.5	0.7	1.1	0.9	0.4	0.9
CHARPY IMPACT VALUE, FT-LB. (1/4 IN. SQUARE BARS)[b]											
C	......	1.25	1.50	1.75[d]	1.25	1.50	1.25	1.25	1.50	1.25	1.50
D	......	1.25	1.50	1.50[d]	1.25	1.50	1.50	1.50	2.00	1.50	1.75
G	1.17	1.50	1.75	1.50[d]	1.00	1.50	1.25	1.25	1.50	1.50	1.50
S	......	2.50	3.00	2.50[d]	2.50	2.75	2.50	3.00	3.50	2.75	3.25
W	1.5	1.00	1.25	1.00[d]	0.75	1.00	1.00	1.00	1.25	1.25	1.00

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

[e] Broke in fillet.

ALLOY NO. VI.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	2.0	3.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	1.91	2.96	0.35	1.30	0.66	0.05	0.42	92.35	nil
Producer D	1.98	3.19	nil	1.53	0.04	0.07	0.33	92.87	nil
Producer G	2.06	3.23	nil	1.98	0.03	0.01	0.01	92.68	nil
Producer S	2.18	3.27	nil	1.86	0.02	0.02	0.04	92.61	nil
Producer W	2.16	5.02	nil	3.38	0.06	0.01	0.16	89.21	nil

Producer	As Cast	5-yr. Indoor Exposure				As Cast	5-yr. Indoor Exposure			
		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.		Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
	TENSILE STRENGTH, LB. PER SQ. IN. (1/4 IN. DIAMETER ROUND BARS)[c]					ELONGATION IN 2 IN., PER CENT (1/4 IN. DIAMETER ROUND BARS)[c]				
C	29 330	31 300	32 100	31 100	31 400	3.5	4.0	3.5	3.4	3.5
D	26 460	29 000	30 400	27 500	29 700	3.3	2.7	2.3	2.5	2.3
G	29 440	32 100	31 500	32 600	32 100	3.8	4.2	3.5	3.9	3.9
S	30 440	33 400	33 000	32 000	34 100	4.2	4.4	3.3	3.8	4.3
W	32 020	33 800	34 100	33 300	34 500	1.6	1.7	1.2	1.4	2.0
	CHARPY IMPACT VALUE, FT-LB. (1/4 IN. SQUARE BARS)[b,c]									
C	......	3.00	3.75	2.75	3.75					
D	......	4.00	4.25	4.00	4.00					
G	6.1	4.25	4.50	4.25	4.75					
S	5.5	5.00	5.00	4.25	5.75					
W	2.4	1.75	2.25	1.75	2.00					

[a] By difference.

[b] Average of two tests on each specimen.

[c] This alloy not exposed outdoors.

ALLOY No VII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	4.0	5.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	3.53	5.11	0.09	1.45	0.20	0.01	0.43	89.18	nil
Producer D	3.86	5.18	0.04	1.51	0.05	0.04	0.38	88.94	nil
Producer G	3.92	4.83	nil	1.56	0.16	nil	0.08	88.11	Tin 0.76 Lead 0.48
Producer S	3.78	5.08	0.14	1.86	0.02	0.01	0.12	89.21	nil
Producer W	3.53	5.70	nil	3.07	0.05	nil	0.22	87.43	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)											
C	35 150	36 300	36 900	[c]	35 400	35 400	37 600	37 800	36 800	37 600	37 500
D	28 070	29 600	29 600	[c]	31 300	28 900	30 300	31 600	32 300	29 200	29 300
G	29 710	30 300	32 500	[c]	30 900	29 500	31 300	33 100	32 200	32 300[e]	31 300
S	33 660	36 700	35 600	[c]	35 400	36 100	35 700	36 900	34 900	[c]	36 000
W	32 240	32 800	31 800	[c]	33 200	32 400	34 700	35 600	33 200	34 600	35 900
ELONGATION IN 2 IN., PER CENT (¼ IN. DIAMETER ROUND BARS)											
C	3.4	2.5	2.5	[c]	3.0	2.2	3.2	3.0	2.4	2.6	3.2
D	1.2	1.3	1.1	[c]	3.0	1.5	0.8	1.2	1.4	0.7	0.5
G	1.8	1.7	1.4	[c]	1.8	1.5	1.5	1.6	1.3	1.3[e]	1.0
S	1.3	1.0	0.9	[c]	1.3	1.0	1.1	2.0	1.1	[c]	1.3
W	1.4	0.5	0.8	[c]	1.2	1.0	0.9	1.3	1.0	0.9	......
CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b]											
C	3.5	2.25	3.00	2.50[d]	2.25	2.75	2.50	2.25	2.75	2.50	2.50
D	......	1.00	1.50	1.50[d]	1.25	1.25	1.25	1.25	1.50	1.50	1.75
G	3.0	1.75	1.75	1.75[d]	1.75	2.00	2.25	1.75	2.50	2.00	2.50
S	2.3	1.25	1.75	1.75[d]	1.50	1.75	1.50	1.50	1.75	[c]	2.00
W	1.7	1.00	1.25	1.25[d]	0.75	1.00	1.25	1.25	1.50	1.25	1.25

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

[e] Average of ten specimens (mistake in loading racks resulted in including two groups of round specimens from producer G).

ALLOY No. VIII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	1.5	0.75	2.25	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	1.56	0.46	1.50	1.67	0.02	0.01	0.03	94.75	nil
Producer D	1.90	0.85	2.22	1.70	0.05	0.03	0.10	93.15	nil
Producer G	1.63	1.43	1.84	1.58	0.10	0.01	nil	93.41	nil
Producer S	1.85	0.95	2.38	1.63	0.06	0.03	0.05	93.05	nil
Producer W	0.45	2.06	0.90	3.52	0.08	0.01	0.07	92.91	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)											
C	31 110	32 200	31 400	[c]	31 300	32 800	32 300	32 500	32 000	32 300	32 900
D	24 640	27 800	25 600	[c]	25 400	25 800	26 800	27 100	27 200	28 000	27 400
G	27 990	26 500	29 000	[c]	25 200	27 300	25 800	29 000	28 800	27 700	28 900
S	33 720	34 100	33 400	[c]	34 500	33 900	34 600	35 000	34 400	34 800	34 600
W	29 290	30 400	30 000	[c]	30 700	30 800	31 500	31 400	30 800	31 100	31 000
ELONGATION IN 2 IN., PER CENT (¼ IN. DIAMETER ROUND BARS)											
C	6.5	5.4	5.3	[c]	6.2	5.6	5.9	6.1	5.2	5.5	5.9
D	2.5	3.0	2.4	[c]	2.5	2.5	2.3	2.9	2.7	3.0	2.4
G	2.9	3.2	3.4	[c]	3.0	3.0	2.3	3.9	2.9	3.1	3.1
S	5.2	4.1	4.0	[c]	5.7	4.0	5.2	5.1	5.1	5.2	4.8
W	5.2	4.5	4.7	[c]	5.4	5.0	4.9	5.6	4.7	5.9	4.9
CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b]											
C	5.2	4.00	4.00	4.75[d]	4.00	4.00	4.00	3.75	4.25	4.00	4.25
D	......	2.75	3.00	3.25[d]	3.00	3.00	3.00	2.75	3.25	3.25	3.50
G	......	3.75	3.75	4.00[d]	3.25	3.50	3.75	3.50	3.75	3.25	3.75
S	5.6	4.50	4.75	5.00[d]	4.25	5.00	4.25	4.50	5.25	4.50	4.75
W	9.4	5.25	4.25	5.50[d]	5.25	5.25	5.50	4.75	6.50	5.75	5.75

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. IX.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition......	4.0	1.5	4.0	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C..............	4.12	2.30	4.31	1.19	0.63	0.01	0.28	87.16	nil
Producer D..............	3.86	1.64	3.78	1.15	0.04	0.04	0.23	89.26	nil
Producer G..............	4.07	1.46	3.68	1.74	0.03	0.01	nil	89.01	nil
Producer S..............	4.15	1.55	3.83	1.68	0.06	0.02	0.12	88.59	nil
Producer W..............	3.28	3.58	1.06	4.97	0.08	0.01	0.18	86.84	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C....................	31 950	36 200	37 100	[c]	37 000	35 700	37 000	39 700	37 100	35 100	40 000
D....................	25 770	28 200	28 000	[c]	26 800	27 900	28 500	27 800	28 000	28 700	28 600
G....................	30 950	32 400	31 900	[c]	32 400	32 100	33 100	34 700	31 600	31 500	32 800
S....................	35 950	36 900	36 000	[c]	37 400	36 800	38 400	39 300	37 600	38 200	38 700
W....................	36 680	38 600	38 900	[c]	38 700	37 900	39 100	39 700	39 800	36 200	40 900
ELONGATION IN 2 IN., PER CENT ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C....................	1.1	0.5	0.9	[c]	1.0	0.5	0.8	1.3	0.6	0.4	0.5
D....................	1.0	0.9	1.0	[c]	1.0	1.0	0.7	1.5	1.0	1.0	1.5
G....................	1.8	1.5	1.5	[c]	1.4	1.6	1.7	2.0	1.5	1.6	1.9
S....................	1.9	1.3	1.6	[c]	2.0	1.5	2.0	1.9	1.5	1.9	1.5
W....................	1.7	1.0	1.3	[c]	1.5	1.0	1.8	1.0	1.1	1.7	1.4
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]											
C....................	1.9	1.00	1.25	1.50[d]	1.00	1.25	1.00	1.25	1.25	1.25	1.00
D....................	......	1.25	1.25	1.25[d]	1.25	1.25	1.50	1.25	1.50	1.25	1.50
G....................	2.8	1.50	1.75	1.75[d]	1.50	2.00	1.75	2.00	2.25	1.75	2.00
S....................	2.7	1.50	1.75	2.00[d]	1.75	1.75	2.00	1.75	2.00	2.00	2.00
W....................	2.6	1.25	1.50	1.50[d]	1.50	1.50	1.75	1.75	2.25	1.75	2.00

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. X.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition......	......	2.0	5.0	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C..............	0.44	2.06	4.39	1.05	0.73	0.09	0.09	91.5	nil
Producer D..............	0.20	2.30	4.54	1.00	0.05	0.04	0.27	91.60	nil
Producer G..............	0.52	1.93	4.61	1.47	0.04	0.01	0.08	91.34	nil
Producer S..............	0.32	2.03	4.89	1.63	0.07	0.04	0.13	90.89	nil
Producer W..............	0.76	1.78	4.29	1.88	0.06	trace	0.24	90.99	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C....................	33 150	34 100	34 400	[c]	33 900	34 000	34 500	34 700	33 700	34 700	34 600
D....................	23 690	24 400	23 400	[c]	23 700	24 200	22 600	23 800	23 000	24 000	21 400
G....................	27 780	28 600	27 900	[c]	28 100	27 400	28 600	28 900	27 100	28 500	28 100
S....................	31 530	31 300	32 000	[c]	31 700	31 800	32 300	32 200	31 900	32 900	31 800
W....................	28 630	30 000	28 400	[c]	29 600	30 300	29 900	29 800	29 500	29 900	30 700
ELONGATION IN 2 IN., PER CENT ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C....................	3.0	2.2	3.1	[c]	2.8	2.0	3.1	2.8	2.6	2.9	3.2
D....................	1.7	2.0	1.9	[c]	2.0	2.2	1.7	1.9	1.5	2.0	1.8
G....................	2.2	2.0	2.0	[c]	2.3	1.5	2.5	2.6	1.9	2.3	2.0
S....................	2.0	2.0	2.3	[c]	2.8	2.0	2.6	2.7	2.5	2.9	2.1
W....................	2.3	1.9	2.0	[c]	2.5	2.0	2.0	2.3	2.1	2.4	2.6
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]											
C....................	3.2	2.50	2.75	2.75[d]	2.50	3.00	3.25	2.50	2.75	2.75	2.75
D....................	......	2.00	2.00	2.25[d]	1.75	2.00	2.25	2.25	1.75	2.00	2.00
G....................	2.0	2.00	2.50	2.50[d]	2.50	2.50	2.25	2.25	2.75	2.00	2.50
S....................	3.3	2.75	3.00	3.00[d]	2.75	3.00	3.00	3.00	3.25	3.00	3.50
W....................	3.2	2.50	2.50	2.50[d]	2.25	2.75	2.25	2.25	2.75	2.25	3.00

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. XI.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	2.0	8.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	2.0	7.48	0.67	0.99	0.70	0.02	0.10	88.04	nil
Producer D	0.33	7.95	nil	1.40	0.04	0.03	0.51	89.74	nil
Producer G	2.09	7.65	nil	0.90	0.03	0.03	0.06	89.08	Tin 0.16
Producer S	2.07	7.30	0.21	1.92	0.02	0.04	0.08	88.36	nil
Producer W	1.46	6.86	0.37	2.91	0.04	0.01	0.36	87.99	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C	36 590	32 400	35 900	[c]	36 400	35 600	36 000	38 400	37 500	38 700	38 300
D	28 650	26 200	29 700	[c]	27 800	26 400	29 600	30 000	29 500	29 200	30 500
G	31 000	30 800	32 000	[c]	32 800	30 100	33 000	33 300	32 500	33 200	32 500
S	33 810	36 100	33 300	[c]	34 500	34 900	35 400	35 400	33 700	34 900	34 600
W	23 540	30 400	30 400	[c]	29 600	31 200	31 300	30 700	31 000	28 500	31 600
ELONGATION IN 2 IN., PER CENT ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C	3.2	2.2	2.9	[c]	2.8	2.7	2.1	3.4	2.8	3.2	3.2
D	2.0	1.0	2.4	[c]	2.3	1.5	1.9	1.7	1.9	2.0	1.0
G	2.2	1.0	1.9	[c]	2.0	1.6	2.1	2.6	2.2	1.9	1.8
S	1.1	1.2	1.4	[c]	1.0	1.0	1.7	1.7	1.1	2.0	1.3
W	1.1	1.1	0.7	[c]	1.0	1.0	1.1	1.2	0.9	1.1	0.8
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]											
C	3.6	2.00	2.50	2.50[d]	2.50	2.50	2.25	2.25	2.75	2.25	2.50
D	......	2.50	2.75	3.00[d]	2.75	3.00	3.00	2.75	3.25	2.75	3.00
G	3.7	1.75	2.75	2.75[d]	2.50	3.00	2.75	2.25	3.00	2.50	2.75
S	2.5	1.50	1.75	2.00[d]	1.75	2.00	2.00	2.25	2.25	2.25	2.25
W	1.6	1.00	1.25	1.25[d]	1.25	1.25	1.25	1.25	1.25	1.25	1.25

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

ALLOY NO. XII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Manganese, per cent	Magnesium, per cent	Zinc, per cent	Aluminum, per cent[a]	Other Elements, per cent
Nominal composition	8.0	1.0	......	1.5 to 2.0	0.05 max.	0.05 max.	......	Remainder	......
Producer C	7.62	0.72	0.10	1.74	0.01	0.02	0.04	89.75	nil
Producer D	7.86	1.20	0.04	1.60	0.02	0.18	0.14	88.96	nil
Producer G	7.90	1.17	nil	1.00	0.02	0.03	0.07	89.41	Tin 0.4
Producer S	7.55	1.48	nil	1.97	0.01	0.03	0.09	88.87	nil
Producer W	6.83	3.08	0.03	2.57	0.05	0.01	0.12	87.31	nil

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure			
		Key West, Fla.	Sandy Hook, N. J.	Rochester, N. Y.	Altoona, Pa.	New York, N. Y.	State College, Pa.	Coco Solo, C. Z.	Cambridge, Mass.	New Kensington, Pa.	Hanover, N. Mex.
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C	34 430	36 200	36 100	[c]	37 000	35 400	36 800	38 900	37 200	37 700	38 400
D	32 380	30 900	33 000	[c]	33 100	33 400	33 200	35 300	34 900	33 900	36 100
G	29 580	32 500	30 300	[c]	27 900	28 500	29 600	32 300	32 400	34 100	32 900
S	34 800	38 700	34 200	[c]	37 400	36 300	37 100	38 900	36 600	39 500	37 000
W	34 720	37 800	36 100	[c]	37 500	36 400	38 100	38 600	37 900	38 200	39 400
ELONGATION IN 2 IN., PER CENT ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)											
C	2.7	1.9	2.5	[c]	2.0	1.5	1.9	2.5	1.9	2.4	2.5
D	1.0	1.1	1.1	[c]	1.3	0.9	0.6	1.5	0.8	1.0	1.3
G	2.2	1.5	1.1	[c]	1.0	1.0	1.5	2.1	1.5	2.0	1.9
S	2.7	2.0	1.1	[c]	1.7	1.8	1.7	2.1	1.4	1.8	1.5
W	1.5	1.1	0.8	[c]	1.7	0.5	1.3	1.2	1.0	1.2	1.0
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]											
C	3.7	1.75	2.25	2.50[d]	2.25	2.50	2.25	2.00	2.25	2.00	2.25
D	......	1.25	1.50	1.50[d]	1.25	1.50	1.50	2.00	1.75	1.50	1.75
G	3.9	1.50	2.25	1.75[d]	2.00	2.25	2.25	2.25	2.25	2.00	2.25
S	4.0	2.00	2.50	[c]	2.50	2.75	2.50	2.50	3.25	2.75	3.25
W	2.3	1.00	1.25	[c]	1.25	1.25	1.25	1.75	1.75	1.50	1.50

[a] By difference.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] Average of three tests on each specimen.

that periods of this length may induce measurable changes. The data also suggest that change in the plans from those of testing after 1, 3 and 5 yr. to the present 1, 5 and 10-yr. schedule, forced by economic conditions, was fortunate—the old schedule would have produced nothing of very real value. The test data to be secured from the one remaining set of exposed specimens, from a corrosion viewpoint, will apparently be of the greatest value. Until those data become available, accurate comparisons between the several aluminum alloys can hardly be made from the committee's data.

Part II—Zinc Alloys:

The following conclusions can be drawn from the data presented in this report:

1. The superiority of alloys prepared with high-purity zinc (99.99+ per cent pure) over those prepared with high-grade zinc (99.90 per cent pure) which was demonstrated in the 95 C. steam tank is confirmed by the 5-yr. exposures.

Alloy No. XXI differs in composition from alloys Nos. XV and XVI only in that zinc of high purity was used in this alloy. After 5 yr. indoor or outdoor aging, the test bars of this alloy, which was the only alloy prepared with 99.99 per cent pure zinc, alone show no visual intercrystalline oxidation.

2. The steam test causes corrosion due to the combined effect of moisture and heat and also aging changes due to the effect of heat alone. Comparison of the effects of the steam exposure, exposure to dry heat, and the various atmospheric exposures show that the results of the steam test, when properly interpreted, afford a reliable and rapid means of predicting whether intercrystalline corrosion will occur under atmospheric exposure conditions over long periods of time. The variations in the results of exposure at the various test locations are entirely consistent with the variations in temperature and humidity known to exist among those locations.

3. Comparison of changes in impact strength after atmospheric exposure, after steam exposure and after exposure in paraffin at 95 C. show that those changes which have occurred are due almost entirely to the thermal effect and not to corrosion.

NOTE.—Alloy No. XXIII of A.S.T.M. Tentative Specifications for Zinc-Base Alloy Die Castings B 86 – 34 T) [1] is copper-free and is not subject to change of impact strength on aging.

4. Contrary to what was at one time generally believed, alloy No. XVIII (0.5 per cent aluminum, 3 per cent copper, 6 per cent tin, balance Prime Western zinc) is susceptible to intercrystalline oxidation in indoor

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 706 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 252.

ALLOY NO. XIII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	0.25	5.0	......	......	......	......	Remainder
Producer C	0.23	4.90	nil	0.049	0.027	0.03	Remainder
Producer D	0.33	4.62	0.0032	0.036	0.046	0.027	Remainder
Producer R	0.25	4.45	0.003	0.042	0.0099	0.044	Remainder
Producer T	0.24	5.44	0.0028	0.040	0.079	0.003	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
C	22 800	10 100	20 300	[c]	18 700	20 300	20 800	15 400	10 000	20 800	13 500	10 700	5 300	[d]	none
D	28 900	14 700	22 500	[c]	23 300	23 500	23 600	15 600	15 500	17 400	20 100	9 100	5 500	29 000	1, 2, 3, 6, 7, 9, 10
R	24 600	9 300	17 700	[c]	20 100	19 500	21 800	12 900	15 900	19 900	21 000	1 700	[e]	25 000	1, 2, 3, 5, 7, 9, 10
T	29 200	10 000	17 300	[c]	19 700	20 700	21 200	9 600	12 800	15 600	20 800	8 700	9 200	28 000	1, 2, 3, 5, 7, 9, 10
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
C	1.2	0	0.8	[c]	0.5	0.4	0	0	0	0.5	0	0.5	0.2	[d]	
D	0.6	0	0.7	[c]	1.0	0.4	0	0.5	0	0.5	0	0.3	0.1	0.3	
R	0.6	0	1.0	[c]	1.0	0.5	0.3	0.3	0	0.5	0	[d]	0	0.3	
T	1.1	0	1.0	[c]	1.0	0.4	0.2	0	0	0.5	0	0.3	0.6	0.5	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
C	0.75	0	0.50	[c]	0.25	0.25	0	0	0.50	0.25	0.50	[d]	[d]	[d]	
D	1.00	0	0.50	[c]	0.50	0.75	0	0	0.50	0.25	0.50	0.25	0.25	0.50	
R	0.75	0	0.50	[c]	0.50	0.75	0	0	0.50	0.50	0.50	[d]	0.25	0.50	
T	1.00	0	0.50	[c]	0.50	0.25	0	0	0.50	0.50	0.75	0.25	0.25	0.50	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
C	......	0.0123	0.0021	[c]	0.0016	0.0019	0.0010	0.0083	0.0013	0.0039	0.0003	0.0192[f]	0.0534[f]	......	
D	......	0.0128	0.0028	[c]	0.0020	0.0022	0.0018	0.0115	0.0043	0.0051	0.0007	0.0456[f]	0.0762[f]	......	
R	......	0.0152	0.0037	[c]	0.0021	0.0041	0.0024	0.0145	0.0035	0.0036	0.0009	0.0396[f]	0.0672[f]	......	
T	......	0.0161	0.0066	[c]	0.0045	0.0068	0.0035	0.0156	0.0042	0.0044	0.0008	0.0180[f]	0.0372[f]	......	

[a] High-grade zinc.
[b] Average of two tests on each specimen.
[c] No specimens available.
[d] No specimens tested.
[e] Specimens disintegrated.
[f] $\frac{1}{2}$-in. section of flat tension bars measured. This value was increased six times.
[g] No specimens from the Rochester location nor for alloy No. XIII C from State College were available for visual examination for intercrystalline oxidation.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	4.0	3.0	......	......	......	......	Remainder
Producer C	3.37	3.48	nil	0.035	0.037	nil	Remainder
Producer D	3.87	3.21	0.0024	0.035	0.035	0.029	Remainder
Producer R	3.79	4.45	0.0049	0.034	0.012	0.041	Remainder
Producer S	4.21	3.81	0.0050	0.044	0.027	0.003	Remainder
Producer T	3.83	2.86	0.0017	0.040	0.002	0.011	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)															
C	45 300	18 000	29 600	[c]	32 700	27 700	30 800	12 700	23 900	26 600	31 300	10 900	5400	[d]	1, 2, 3, 5, 6, 7, 8, 9, 10
D	43 200	5 600	28 900	[c]	30 900	30 100	30 300	[c]	19 000	20 000	29 000	6 400	0	38 800	1, 2, 3, 5, 6, 8, 9, 10
R	41 900	3 800	24 300	[c]	26 200	25 700	26 200	[d]	12 400	14 400	27 100	0	0	37 300	1, 2, 3, 5, 6, 8, 9, 10
S	46 800	16 200	35 700	[c]	36 700	33 300	35 600	[c]	27 800	27 900	35 200	7 300	0	38 400	1, 2, 3, 5, 6, 8, 9, 10
T	42 000	11 800	27 200	[c]	30 100	28 000	29 500	[c]	23 700	21 800	31 000	9 600	3300	36 000	1, 2, 3, 5, 6, 8, 9, 10
ELONGATION IN 2 IN., PER CENT (MEASURED ON ¼ IN. DIAMETER ROUND TENSION BARS)															
C	4.1	0	1.0	[c]	1.0	0.5	0	0	0	0.5	0	0.5	0.2	[d]	
D	2.5	0	0.5	[c]	0.5	0.4	0	[c]	0	0.5	0	0.3	0	0.5	
R	1.2	0	0.5	[c]	0.5	0.2	0	[d]	0	0.5	0	0	0	0.7	
S	3.8	0.1	1.0	[c]	1.1	0.5	0	[c]	0	0.5	0	0.2	0	0.9	
T	4.2	0	1.0	[c]	1.0	0.5	0.5	[d]	0	0.5	0	1.0	0.1	2.3	
CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b]															
C	2.75	0	0.50	[c]	0.50	0.25	0	0	0.50	0.25	0.50	[d]	[d]	[d]	
D	3.25	0	0.50	[c]	0.25	0.25	0	[c]	0.50	0.25	0.50	0.25	[d]	0.75	
R	2.25	0	0.50	[c]	0.50	0.25	0	[d]	0.25	0.25	0.50	[d]	[d]	0.50	
S	5.00	0	0.50	[c]	0.50	0.75	0	0	0.50	0.25	0.50	0.25	0.25	0.75	
T	7.00	0	0.50	[c]	0.50	0.50	0.25	[c]	0.50	0.25	0.50	0.25	0.25	1.00	
EXPANSION, IN. PER 6 IN. (MEASURED ON ¼ IN. SQUARE IMPACT BARS)															
C	......	0.0376	0.0242	[c]	0.0198	0.0208	0.0210	0.0765	0.0252	0.0311	0.0187	0.0330[f]	0.0840[f]	......	
D	......	0.1063	0.0322	[c]	0.0280	0.0309	0.0254	0.1445	0.0371	0.0431	0.0252	0.2526[f]	0.3930[f]	......	
R	......	0.1857	0.0545	[c]	0.0452	0.0521	0.0457	[d]	0.0668	0.0799	0.0382	0.4266[f]	0.4992[f]	......	
S	......	0.0525	0.0236	[c]	0.0181	0.0226	0.0189	0.0740	0.0230	0.0297	0.0195	0.1830[f]	0.3642[f]	......	
T	......	0.0596	0.0277	[c]	0.0265	0.0289	0.0254	0.0863	0.0287	0.0307	0.0211	0.0774[f]	[e]	......	

[a] High-grade zinc.
[b] Average of two tests on each specimen.
[c] No specimens available.
[d] No specimens tested.
[e] Specimens disintegrated.
[f] ¾-in. section of flat tension bars measured. This value was increased six times.
[g] No specimens from the Rochester location nor for Alloy No. XIV D, R, S, T from Coco Solo were available for visual examination for intercrystalline oxidation.

ALLOY NO. XV.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	4.0	3.0	0.1	......	......	......	Remainder
Producer C	3.96	3.00	0.10	0.032	0.013	nil	Remainder
Producer D	4.02	2.97	0.10	0.027	0.051	0.005	Remainder
Producer R	3.83	3.07	0.07	0.032	0.012	0.009	Remainder
Producer S	4.04	2.75	0.14	0.041	0.024	0.016	Remainder
Producer Z	3.87	3.11	0.11	0.060	0.025	0.0007	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
C	48 700	43 900	51 100	49 100	52 800	48 800	54 000	49 900	54 200	53 600	53 200	38 500	33 400	[d]	2
D	47 000	35 400	45 100	46 200	45 800	43 800	50 600	36 100	46 000	48 000	49 500	29 600	25 200	40 500	2, 3, 4, 5, 7, 10
R	50 600	51 000	51 700	55 500	53 200	52 500	55 600	52 500	53 200	54 900	55 400	29 200	22 100	40 100	none
S	48 400	33 600	40 300	45 200	43 900	42 300	48 600	41 000	48 500	48 100	49 500	31 100	25 500	41 000	2, 3, 4, 5, 6, 7
Z	43 100	28 700	40 300	41 500	37 400	36 300	39 400	26 100	37 600	42 700	43 500	29 100	23 900	39 000	1, 2, 3, 4, 5, 7, 8, 10
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
C	3.9	0.1	1.6	0.8	1.7	0.8	0.8	0.2	1.7	2.0	1.3	0.5	0.5	[d]	
D	1.7	0	1.6	0.8	0.6	0.4	0.6	0.6	0.7	1.0	0.8	0.6	0.6	0.5	
R	2.3	0.8	1.6	3.1	1.6	0.7	1.0	0.7	1.1	1.5	1.1	0.4	0.1	0.5	
S	2.1	0.1	0.8	1.6	1.1	0.5	0.6	0.5	1.1	1.0	1.2	0.7	0.4	0.6	
Z	5.6	0	2.3	1.6	1.0	0.4	0.1	0	0.5	1.0	0.3	0.3	0.5	0.6	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
C	4.75	0	1.75	[c]	2.00	2.00	1.75	0.75	2.00	1.50	1.75	[d]	[d]	[d]	
D	3.25	0	0.75	[c]	1.00	0.75	0.75	0	0.75	0.75	1.00	0.25	0.25	1.00	
R	7.00	0.75	1.75	[c]	1.75	2.25	2.00	1.00	1.75	1.25	1.75	[d]	0.25	0.75	
S	4.75	0	1.00	[c]	2.00	1.25	1.50	0	1.75	1.25	1.75	0.50	0.25	1.25	
Z	3.00	0	1.00	[c]	1.00	0.75	0.50	0	0.75	0.75	1.00	0.25	0.25	0.75	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
C	......	0.0132	0.0029	[c]	0.0039	0.0030	0.0017	0.0082	0.0042	0.0077	0.0035	0.0102[f]	0.0510[f]	......	
D	......	0.0182	0.0070	[c]	0.0070	0.0066	0.0042	0.0166	0.0068	0.0103	0.0054	0.0324[f]	0.0540[f]	......	
R	......	0.0097	0.0015	[c]	0.0019	0.0020	0.0009	0.0102	0.0023	0.0050	0.0020	0.0336[f]	0.0636[f]	......	
S	......	0.0150	0.0053	[c]	0.0049	0.0050	0.0031	0.0137	0.0050	0.0078	0.0026	0.0378[f]	0.0456[f]	......	
Z	......	0.0150	0.0078	[c]	0.0068	0.0083	0.0052	0.0285	0.0074	0.0089	0.0062	0.0414[f]	0.0882[f]	......	

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[a] High-grade zinc.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[f] $\frac{1}{4}$-in. section of flat tension bars measured. This value was increased six times.

[g] Specimens for Alloy No. XV D from New Kensington, Alloy No. XV R from Key West, and Alloy No. XV Z from New York and New Kensington were not available for visual examination for intercrystalline oxidation.

ALLOY NO. XVI.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	4.0	3.0	0.1	......	......	......	Remainder
Producer C	4.26	3.07	0.11	0.037	0.005	......	Remainder
Producer D	3.99	3.02	0.09	0.045	0.0059	0.004	Remainder
Producer S	4.08	2.82	0.13	0.038	0.0041	0.016	Remainder
Producer Z	3.77	3.04	0.11	0.038	0.002	0.0008	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
C	48 600	40 900	52 000	54 600	52 200	49 300	53 900	48 400	52 000	51 500	51 700	29 100	30 200	[d]	none
D	47 200	38 600	48 600	49 700	49 500	47 200	51 100	39 900	50 700	51 300	50 400	30 600	26 200	42 700	2, 3, 4, 5, 7
S	47 400	30 300	40 700	43 600	42 000	40 800	42 400	33 400	44 100	44 900	45 900	27 800	21 800	40 400	1, 2, 3, 4, 5, 6, 7, 9
Z	41 800	37 200	45 300	44 000	43 400	42 100	43 500	45 700	44 400	46 700	47 900	30 500	22 600	39 100	2, 4
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
C	3.4	0.2	2.3	2.3	1.2	0.5	0.5	0.4	1.0	1.9	0.9	0.5	1.0	[d]	
D	2.1	0	1.6	1.6	1.2	0.5	1.2	0.5	0.7	1.0	0.7	0.7	0.6	0.5	
S	2.4	0.2	0.8	1.6	1.0	0.3	0.6	0.1	0.3	1.0	1.0	0.5	0.4	0.7	
Z	3.2	0.1	1.6	3.1	1.6	0.8	0.5	0.5	1.2	1.0	1.2	0.4	0.3	0.7	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
C	4.75	0.25	1.75	[c]	1.50	2.00	1.50	0.75	1.75	1.25	1.75	[d]	[d]	[d]	
D	5.00	0	1.00	[c]	1.25	1.25	1.50	0.50	1.25	1.00	1.75	0.50	0.25	1.00	
S	6.00	0	1.00	[c]	2.00	1.25	1.25	0	1.50	1.25	1.25	0.50	0.25	1.25	
Z	5.50	0.25	2.50	[c]	2.50	3.50	3.75	1.00	1.25	1.50	1.50	0.25	0.25	1.00	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
C	......	0.0051	0.0152	[c]	0.0051	0.0049	0.0038	0.0123	0.0072	0.0105	0.0064	0.0150[f]	0.0420[f]	......	
D	......	0.0180	0.0051	[c]	0.0049	0.0062	0.0042	0.0146	0.0055	0.0100	0.0043	0.0336[f]	0.0510[f]	......	
S	......	0.0162	0.0059	[c]	0.0047	0.0060	0.0035	0.0158	0.0050	0.0080	0.0031	0.0474[f]	0.1020[f]	......	
Z	......	0.0061	0.0039	[c]	0.0033	0.0032	0.0020	0.0097	0.0020	0.0061	0.0027	0.0144[f]	0.0510[f]	......	

[a] Special-grade zinc—lead and cadmium, together, 0.06 per cent, max.; tin, none; zinc, 99.4 per cent, min.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.

[g] Specimens for Alloy No. XVI C from Key West and Alloy No. XVI Z from New York were not available for visual examination for intercrystalline oxidation.

ALLOY NO. XVII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	3.0	3.0	0.3	......	......	......	Remainder
Producer D	3.07	2.94	0.31	0.027	0.043	0.002	Remainder
Producer S	3.27	2.60	0.26	0.048	0.019	0.003	Remainder
Producer T	3.05	2.84	0.33	0.038	0.004	0.001	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
D	37 500	30 300	36 200	35 500	37 100	35 500	35 200	32 700	30 100	37 800	36 500	25 000	20 800	34 300	2, 3, 4, 5, 6, 7, 10
S	43 900	23 400	37 300	39 400	38 400	36 900	39 200	35 400	40 700	39 500	c	27 000	23 000	37 000	2, 3, 4, 5, 7
T	40 400	24 500	34 200	37 600	36 100	32 200	37 400	34 500	36 400	37 200	37 000	30 300	23 500	33 500	2, 3, 4, 5, 7
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
D	0.6	0.2	1.0	0.5	0.5	0.5	0.2	0.4	0	0.5	0	0.3	0.3	0.4	
S	0.8	0	1.1	0.5	0.5	0.3	0.1	0.4	0	0.5	c	0.6	0.3	0.4	
T	0.6	0	0.9	0.8	0.5	0.2	0.3	0	0	0.5	0	0.4	0.6	0.5	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
D	1.50	0	0.50	c	0.75	0.75	0.50	0.25	0.50	0.75	0.75	0.50	0.25	0.75	
S	2.25	0	0.75	c	1.00	0.75	0.75	0	0.75	0.75	1.00	0.50	0.25	0.75	
T	1.50	0	0.50	c	0.75	0.50	0.50	0.25	0.75	0.75	0.75	0.50	0.25	0.75	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
D	......	0.0162	0.0053	c	0.0037	0.0039	0.0022	0.0094	0.0039	0.0048	0.0029	0.0270[f]	0.0444[f]	......	
S	......	0.0133	0.0061	c	0.0044	0.0053	0.0022	0.0101	0.0041	0.0054	0.0028	0.0504[f]	0.0678[f]	......	
T	......	0.0212	0.0063	c	0.0048	0.0056	0.0022	0.0138	0.0032	0.0055	0.0029	0.0168[f]	0.0582[f]	......	

[a] High-grade zinc.
[b] Average of two tests on each specimen
[c] No specimens available.
[d] No specimens tested.
[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.
[g] Specimens for Alloy No. XVII S from Hanover and Alloy No. XVII T from New York were not available for visual inspection for intercrystalline oxidation.

ALLOY NO. XVIII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	0.5	3.0	......	......	......	6.0	Remainder
Producer C	0.27	2.82	nil	0.64	0.36	6.67	Remainder
Producer S	0.76	3.34	0.0024	1.05	0.43	5.67	Remainder
Producer T	0.32	2.72	0.0076	0.49	0.20	5.93	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
C	24 000	16 400	21 600	21 300	21 200	20 400	21 800	16 800	19 400	20 200	20 900	2 500	5 000	[d]	2
S	23 000	11 200	14 300	13 100	12 600	17 300	13 900	8 300	9 200	13 300	19 000	900	0	19 400	2
T	25 800	10 300	20 600	22 900	20 400	20 800	21 900	8 900	16 000	15 900	21 400	2 400	5 000	26 100	1, 2, 4, 5, 7
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
C	1.0	0	1.0	0.9	1.1	1.0	0.7	0	0	0.5	0	0.2	0	[d]	
S	0.5	0	1.0	1.0	0.5	0.5	0.3	0	0	0.6	0	0	0	0.3	
T	1.1	0	1.0	0.5	1.0	0.4	0	0	0	0.5	0	0.1	0.1	0.6	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
C	1.50	0	0.50	[c]	0.25	0.50	0	0	0.50	0.25	0.50	[d]	[d]	[d]	
S	2.00	0	0.50	[c]	0.50	0.50	0.25	0	0.50	0.25	0.75	0.23	0.25	0.75	
T	1.50	0	0.50	[c]	0.50	0.50	0.25	0	0.50	0.25	0.50	0.25	0.25	0.75	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
C	......	0.0183	0.0058	[c]	0.0075	0.0083	0.0047	0.0214	0.0059	0.0129	0.0039	0.0360[f]	0.1668[f]	......	
S	......	0.0327	0.0088	[c]	0.0155	0.0116	0.0117	0.0375	0.0123	0.0209	0.0109	0.1686[f]	0.3402[f]	......	
T	......	0.0288	0.0116	[c]	0.0117	0.0108	0.0108	0.0268	0.0087	0.0109	0.0061	0.0606[f]	0.2124[f]	......	

[a] Prime Western zinc.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.

[g] Specimen for Alloy No. XVIII T from New York was not available for visual examination for intercrystalline oxidation.

ALLOY NO. XIX.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Nickel, per cent	Zinc, per cent[a]
Nominal composition	4.0	2.0	0.1	......	......	......	0.02	Remainder
Producer D	4.18	2.19	0.10	0.048	0.005	0.001	0.022	Remainder
Producer R	3.70	1.94	0.08	0.041	0.011	0.006	0.013	Remainder
Producer Z	4.00	2.01	0.11	0.035	0.004	0.0007	0.030	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
D	46 500	32 000	37 200	36 900	38 800	35 800	39 700	34 300	40 200	39 500	41 100	31 900	27 100	40 900	2, 3, 4, 5, 6, 7
R	45 600	28 500	39 000	39 800	38 100	35 700	40 900	33 300	40 500	39 400	41 100	29 800	25 500	39 000	2, 4, 5, 6, 7
Z	39 000	33 300	36 300	35 000	35 000	33 700	34 600	33 400	35 700	33 200	35 100	30 700	26 500	34 200	2
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
D	2.0	0.5	1.2	1.0	1.5	0.9	0.8	0.2	0	1.0	0	0.8	0.3	1.4	
R	1.4	0.1	1.4	0.5	1.2	0.5	1.4	0.1	0	0.7	0	0.6	0.4	1.5	
Z	2.4	0.6	2.7	2.0	1.8	1.8	1.0	0.8	0	1.8	0	0.9	0.5	1.3	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
D	6.00	0.50	1.50	[c]	3.75	2.75	4.50	0.25	1.75	2.00	3.00	0.50	0.50	1.75	
R	5.00	0.50	2.50	[c]	5.25	4.25	4.25	0.50	3.75	2.75	4.50	[d]	0.25	1.25	
Z	5.50	1.00	3.50	[c]	6.00	5.75	7.25	4.25	5.25	4.50	5.50	0.75	0.50	2.25	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
D	......	0.0089	0.0035	[c]	0.0029	0.0026	0.0008	0.0071	0.0016	0.0022	0.0008	0.0270[f]	0.0456[f]	......	
R	......	0.0054	0.0005	[c]	0.0002	0.0001	−0.0014	0.0063	−0.0004	0.0001	−0.0010	0.0198[f]	0.0372[f]	......	
Z	......	0.0056	0.0023	[c]	0.0018	0.0011	0.0007	0.0022	0.0004	0.0012	0.0006	0.0102[f]	0.0276[f]	......	

[a] Special-grade zinc—lead and cadmium, together, 0.06 per cent, max.; tin, none; zinc, 99.4 per cent min.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.

[g] Specimen for Alloy No. XIX Z from New York was not available for visual examination for intercrystalline oxidation.

ALLOY NO. XX.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	4.0	3.0	......	......	......	......	Remainder
Producer C	4.09	2.73	nil	0.027	0.32	0.01	Remainder
Producer D	3.88	3.14	0.0022	0.24	0.030	0.14	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[g]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. (¼ IN. DIAMETER ROUND BARS)															
C	35 700	20 500	34 900	35 600	33 000	33 400	35 700	15 700	32 900	29 400	35 200	0	0	[d]	2, 3, 4, 5, 6, 7, 9
D	40 800	17 700	32 900	34 600	34 200	31 300	33 300	[c]	15 300	20 900	27 800	5700	0	37 100	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
ELONGATION IN 2 IN., PER CENT (MEASURED ON ¼ IN. DIAMETER ROUND TENSION BARS)															
C	1.7	0	0.5	1.4	0.5	0.5	0	0	0	0.5	0	0	0	[d]	
D	1.3	0	0.5	0.5	0.5	0.5	0.2	[c]	0	0.5	0	0.1	0	0.5	
CHARPY IMPACT VALUE, FT-LB. (¼ IN. SQUARE BARS)[b]															
C	[d]	0	0.50	[c]	0.50	0.25	0	0	0.50	0.25	0.50	[d]	[d]	[d]	
D	2.25	0	0.50	[c]	0.25	0.25	0	[c]	0.50	0.25	0.50	[d]	[d]	0.50	
EXPANSION, IN. PER 6 IN. (MEASURED ON ¼ IN. SQUARE IMPACT BARS)															
C	......	0.0681	0.0209	[c]	0.0161	0.0207	0.0152	0.0700	0.0188	0.0310	0.0158	[e]	[e]	[d]	
D	......	0.1685	0.0381	[c]	0.0362	0.0420	0.0354	[c]	0.0372	0.0532	0.0274	[e]	[e]	[d]	

[a] 99.75 per cent pure zinc.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[e] Specimens disintegrated.

[g] Specimen for Alloy No. XX C from State College was not available for visual examination for intercrystalline oxidation.

ALLOY NO. XXI.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent[a]
Nominal composition	4.0	3.0	0.1	......	......	......	Remainder
Producer D	3.93	2.95	0.12	0.0032	0.0067	0.002	Remainder
Producer R	3.80	2.94	0.09	0.0023	0.0027	0.006	Remainder
Producer S	3.86	2.92	0.12	0.007	0.0029	0.002	Remainder
Producer T	4.00	2.93	0.12	0.0025	0.0020	0.0008	Remainder
Producer Z	4.03	3.01	0.11	0.0030	0.0012	nil	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[e]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
D	47 200	50 700	50 400	51 200	49 800	49 800	51 700	46 900	47 300	53 200	52 500	41 400	41 600	43 200	none
R	50 400	51 000	55 900	56 500	52 000	52 700	54 800	52 100	55 700	54 800	55 100	42 800	36 500	42 400	none
S	48 200	50 500	46 100	51 300	46 600	47 900	51 000	50 400	50 600	51 800	51 400	40 600	36 800	45 500	none
T	48 200	46 500	45 400	50 200	46 600	46 500	47 400	46 000	49 000	48 300	50 100	40 800	41 000	40 900	none
Z	44 400	49 400	49 900	46 100	45 500	46 800	49 300	47 400	51 200	50 100	47 900	41 000	40 500	39 900	none
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
D	2.6	0.6	3.1	2.3	1.4	1.2	0.9	0.8	0.8	1.8	1.8	0.8	1.3	0.9	
R	3.0	0.4	2.3	3.1	1.4	1.0	0.5	0.8	1.3	2.2	1.1	1.4	0.8	0.9	
S	3.6	1.0	3.6	3.1	1.5	1.2	2.2	1.3	1.3	2.1	2.0	0.8	0.8	1.2	
T	3.1	0.5	3.9	3.1	2.1	2.2	0.8	0.5	0.9	1.9	1.3	1.2	0.9	0.9	
Z	2.8	0.2	3.1	2.3	2.6	2.2	0.9	0.8	1.4	2.0	1.2	1.2	0.8	0.8	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
D	8.25	1.00	2.00	[c]	1.75	3.00	2.25	1.50	2.25	1.25	2.00	1.00	1.00	1.50	
R	8.00	1.25	2.25	[c]	1.75	3.50	2.75	1.50	2.25	1.50	2.50	[d]	0.50	1.00	
S	9.00	1.50	3.50	[c]	2.25	4.25	5.00	1.75	2.00	1.50	2.00	1.00	0.75	1.50	
T	5.75	1.00	3.50	[c]	3.00	4.00	1.75	1.50	1.75	1.50	1.75	1.00	0.75	1.50	
Z	6.00	0.75	3.00	[c]	3.00	3.50	2.00	1.25	1.75	1.25	2.00	1.00	0.75	1.00	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
D	......	0.0098	0.0032	[c]	0.0022	0.0030	0.0024	0.0092	0.0052	0.0074	0.0043	0.0096[f]	0.0150[f]	......	
R	......	0.0070	0.0012	[c]	−0.0005	0.0007	−0.0003	0.0074	0.0031	0.0053	0.0015	0.0108[f]	0.0228[f]	......	
S	......	0.0037	−0.0001	[c]	−0.0005	0.0000	−0.0009	0.0046	0.0011	0.0020	0.0013	0.0168[f]	0.0294[f]	......	
T	......	0.0107	0.0033	[c]	0.0028	0.0048	0.0029	0.0098	0.0048	0.0071	0.0036	0.0066[f]	0.0114[f]	......	
Z	......	0.0070	0.0019	[c]	0.0017	0.0023	0.0010	0.0060	0.0008	0.0047	0.0015	0.0060[f]	0.0090[f]	......	

[a] High-purity zinc.

[b] Average of two tests on each specimen.

[c] No specimens available.

[d] No specimens tested.

[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.

[e] Specimens for Alloy No. XXI D from New Kensington; Alloy No. XXI R from Key West and New Kensington; Alloy No. XXI T from New York and State College; and Alloy No. XXI Z from New York were not available for visual examination for intercrystalline oxidation.

ALLOY NO. XXII.

COORDINATED CHEMICAL ANALYSES—ALL LABORATORIES.

	Aluminum, per cent	Copper, per cent	Magnesium, per cent	Lead, per cent	Cadmium per cent	Tin, per cent	Zinc, per cent[a]
Nominal Composition	0.5	3.0	......	......	......	6.0	Remainder
Producer C	0.35	2.77	nil	0.037	0.002	5.88	Remainder

Producer	As Cast	5-yr. Outdoor Exposure						5-yr. Indoor Exposure				95 C. Steam		95 C. Paraffine, 20 Days	Visual Inspection Showed Intercrystalline Oxidation at Location Numbers[e]
		(2) Key West, Fla.	(3) Sandy Hook, N. J.	(4) Rochester, N. Y.	(5) Altoona, Pa.	(6) New York, N. Y.	(1) State College, Pa.	(7) Coco Solo, C. Z.	(10) Cambridge, Mass.	(9) New Kensington, Pa.	(8) Hanover, N. Mex.	10 Days	20 Days		
TENSILE STRENGTH, LB. PER SQ. IN. ($\frac{1}{4}$ IN. DIAMETER ROUND BARS)															
C	26 300	12 000	18 900	[c]	15 600	18 300	16 300	10 000	12 900	14 800	13 600	7 800	10 600	[d]	3
ELONGATION IN 2 IN., PER CENT (MEASURED ON $\frac{1}{4}$ IN. DIAMETER ROUND TENSION BARS)															
C	0.8	0	0.5	[c]	0.5	0.5	0	0	0	0.5	0	0	0.5	[d]	
CHARPY IMPACT VALUE, FT-LB. ($\frac{1}{4}$ IN. SQUARE BARS)[b]															
C	1.50	0	0.50	[c]	0.50	0.25	0	0	0.50	0.25	0.50	[d]	[d]	[d]	
EXPANSION, IN. PER 6 IN. (MEASURED ON $\frac{1}{4}$ IN. SQUARE IMPACT BARS)															
C	......	0.0310	0.0154	[c]	0.0157	0.0141	0.0126	0.0274	0.0131	0.0150	0.0137	0.0294[f]	0.1086[f]	[d]	

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[a] High-grade zinc.
[b] Average of two tests on each specimen.
[c] No specimens available.
[d] No specimens tested.
[f] $\frac{3}{4}$-in. section of flat tension bars measured. This value was increased six times.
[e] Specimen for Alloy No. XXII C from Rochester was not available for visual examination for intercrystalline oxidation.

and outdoor exposures. This is in accordance with the findings in the 95 C. steam test.

Discussion.—The zinc alloys tested fall into two related groups. Most important is the group containing 4 per cent aluminum and 2 or 3 per cent copper. Some of this group contain magnesium and one also contains nickel to retard intercrystalline oxidation. The several alloys vary both in the nominal purity of the zinc used and in the actual purity of the final alloys as made by different producers. The variation in behavior of the various alloys of this group in both steam and atmospheric exposure tests correlates very closely with the purity of the alloys in respect to lead, tin and cadmium and with presence or absence of magnesium and nickel.

The alloys of this group in ascending order of their permanence are Nos. XX, XIV, XV and XVI (with casts from individual producers varying in purity and similarly in permanence), No. XIX and finally, far superior to all other zinc alloys of any group both in purity and permanence, alloy No. XXI. Alloy No. XVII in spite of poor initial properties has a degree of permanence making it approximately equal in this respect to any alloy made with the same grade of zinc. Alloy No. XXI is of course the only one of the alloys tested now in common use.

Alloys Nos. XIII and XVIII are low in aluminum. Both show intercrystalline oxidation both in steam and after atmospheric exposure.

Respectfully submitted on behalf of the subcommittee,

W. M. PEIRCE,
Chairman.

APPENDIX

DESCRIPTION OF THE PHOTOGRAPHIC INSPECTION OF DIE-CAST SPECIMENS EXPOSED FOR 4 YEARS AT SIX OUTDOOR LOCATIONS

KEY WEST EXPOSURE

Alloy No. I:

Producer C—Completely covered with white corrosion product.
D—Completely covered with white corrosion product.
G—Completely covered with white corrosion product.
S—Completely covered with white corrosion product.
W—Completely covered with white corrosion product.

Alloy No. IV:

Producer C—Some metallic luster remains. Numerous spots of white corrosion product.
D—Numerous spots of white corrosion product. Some pitting.
G—Some metallic luster remains. Numerous spots of white corrosion product.
S—Best appearance of any aluminum specimens exposed at this location. Some parts of the bars still retain a metallic luster. White corrosion product is present.
W—Completely covered with white corrosion product.

Alloy No. V:

Producer C—Some metallic luster remains. Almost covered with white corrosion product.
D—Completely covered with white corrosion product.
G—Some metallic luster remains. Almost covered with white corrosion product.
S—Some metallic luster remains. Numerous spots of white corrosion product.
W—Some metallic luster remains. Almost covered with white corrosion product.

Alloy No. VII:

Producer C—Completely covered with white corrosion product.
D—Completely covered with quite heavy deposit of white corrosion product.
G—Completely covered with quite heavy deposit of white corrosion product.
S—Completely covered with quite heavy deposit of white corrosion product.
W—Completely covered with white corrosion product.

Alloy No. VIII:

Producer C—Some metallic luster remains. Almost completely covered with fine white corrosion product.
D—Some metallic luster remains. Almost completely covered with fine white corrosion product.
G—Some metallic luster remains. Almost completely covered with white corrosion product.
S—Some metallic luster remains. Almost completely covered with white corrosion product.
W—Some metallic luster remains. Almost completely covered with fine white corrosion product.

Alloy No. IX:

Producer C—Completely covered with quite heavy deposits of white corrosion product.
D—Completely covered with quite heavy deposits of white corrosion product.
G—Completely covered with quite heavy deposits of white corrosion product.
S—Completely covered with quite heavy deposits of white corrosion product.
W—Completely covered with quite heavy deposits of white corrosion product.

Alloy No. X:

Producer C—Some metallic luster remains. Almost completely covered with white corrosion product.
D—Some metallic luster remains. Almost completely covered with white corrosion product.
G—Completely covered with white corrosion product.
S—Some metallic luster remains. Almost completely covered with white corrosion product.
W—Some metallic luster remains. Almost completely covered with white corrosion product.

Alloy No. XI:

Producer C—Some metallic luster remains. Almost completely covered with white corrosion product.
D—Some metallic luster remains. Almost completely covered with white corrosion product.
G—Completely covered with white corrosion product.
S—Some metallic luster remains. Almost completely covered with white corrosion product.
W—Some metallic luster remains. Almost completely covered with white corrosion product.

Alloy No. XII:

Producer C—Completely covered with fine white corrosion product.
D—Completely covered with heavy white corrosion product. Some pitting.
G—Completely covered with heavy white corrosion product. Some pitting.
S—Completely covered with very heavy white corrosion product. Considerable pitting. This is the worst of the aluminum specimens exposed at this location.
W—Completely covered with very heavy white corrosion product. Considerable pitting.

Alloy No. XIII:
Producer C—Considerable fine white corrosion product.
D—Considerable white corrosion product.
R—Considerable white corrosion product.
T—Considerable white corrosion product.

Alloy No. XIV:
Producer C—Considerable fine white corrosion product.
D—Some fine white corrosion product.
R—Some fine white corrosion product.
S—Some fine white corrosion product.
T—Considerable fine white corrosion product.

Alloy No. XV:
Producer C—Considerable fine white corrosion product.
D—Considerable fine white corrosion product.
R—Considerable fine white corrosion product.
S—Considerable fine white corrosion product.
Z—Considerable fine white corrosion product.

Alloy No. XVI:
Producer C—Considerable fine white corrosion product.
D—Considerable fine white corrosion product.
S—Considerable fine white corrosion product.
Z—Considerable white corrosion product.

Alloy No. XVII:
Producer D—Considerable white corrosion product.
S—Considerable white corrosion product.
T—Considerable white corrosion product.

Alloy No. XVIII:
Producer C—Considerable white corrosion product.
S—Considerable white corrosion product.
T—Considerable white corrosion product.

Alloy No. XIX:
Producer D—Some fine white corrosion product.
R—Some fine white corrosion product.
Z—Some fine white corrosion product.

Alloy No. XX:
Producer C—Some fine white corrosion product.
D—Some fine white corrosion product.

Alloy No. XXI:
Producer D—Some white corrosion product.
R—Considerable fine white corrosion product.
S—Considerable white corrosion product.
T—Considerable white corrosion product.
Z—Considerable white corrosion product.

Alloy No. XXII:
Producer C—Considerable white corrosion product.

SANDY HOOK EXPOSURE

Alloy No. I:
Producer C—Numerous spots of white corrosion product.
D—No specimens photographed.
G—Numerous spots of white corrosion product.
S—Some metallic luster remains. Numerous spots of white corrosion product.
W—Some metallic luster remains. Almost completely covered with white corrosion product.

Alloy No. IV:

Producer C—Some white corrosion product.
D—Numerous white corrosion product.
G—Some white corrosion product.
S—Numerous spots of white corrosion product.
W—Numerous quite heavy deposits of white corrosion product.

Alloy No. V:

Producer C—Numerous spots of white corrosion product.
D—Numerous quite heavy deposits of white corrosion product.
G—Some white corrosion product.
S—Some white corrosion product.
W—Numerous spots of white corrosion product.

Alloy No. VII:

Producer C—Some white corrosion product.
D—Numerous spots of white corrosion product.
G—Numerous quite heavy deposits of white corrosion product.
S—Numerous spots of white corrosion product.
W—Numerous spots of white corrosion product.

Alloy No. VIII:

Producer C—Some metallic luster remains. Numerous spots of white corrosion product.
D—Some white corrosion product.
G—Some white corrosion product.
S—Some white corrosion product.
W—Some metallic luster remains. Numerous spots of white corrosion product.

Alloy No. IX:

Producer C—Some white corrosion product.
D—Some white corrosion product.
G—Some metallic luster remains. Numerous spots of white corrosion product.
S—Some white corrosion product.
W—Numerous spots of white corrosion product.

Alloy No. X:

Producer C—Numerous spots of white corrosion product.
D—Some metallic luster remains. Numerous spots of white corrosion product.
G—Numerous quite heavy deposits of white corrosion product. Some pitting.
S—No specimens photographed.
W—Some white corrosion product.

Alloy No. XI:

Producer C—Some white corrosion product. Some pitting.
D—Numerous spots of white corrosion product. Some pitting.
G—Numerous spots of white corrosion product.
S—Some white corrosion product.
W—Some fine white corrosion product.

Alloy No. XII:

Producer C—Numerous spots of fine white corrosion product. Some pitting.
D—Some white corrosion product. Some pitting.
G—Numerous spots of fine white corrosion product. Some pitting.
S—Numerous spots of fine white corrosion product. Some pitting.
W—Numerous spots of fine white corrosion product. Some pitting.

Alloy No. XIII:

Producer C—Gray appearance.
D—Gray appearance. Few spots of fine white corrosion product. Some pitting.
R—Gray appearance. Few spots of fine white corrosion product. Some pitting.
T—Gray appearance. Few spots of fine white corrosion product. Some pitting.

Alloy No. XIV:
Producer C—Gray appearance.
D—Gray appearance.
R—Gray appearance.
S—Gray appearance.
T—Gray appearance.

Alloy No. XV:
Producer C—Gray appearance.
D—Gray appearance.
R—Gray appearance.
S—Gray appearance. Few spots of fine white corrosion product.
Z—Gray appearance.

Alloy No. XVI:
Producer C—Gray appearance. Few spots of fine white corrosion product.
D—Gray appearance.
S—Gray appearance.
Z—Gray appearance. Few spots of fine white corrosion product.

Alloy No. XVII:
Producer D—Gray appearance.
S—Gray appearance.
T—No photograph taken.

Alloy No. XVIII:
Producer C—Gray appearance. Some fine white corrosion product.
S—Gray appearance. Few fine white corrosion product.
T—Gray appearance.

Alloy No. XIX:
Producer D—Gray appearance. Few spots of fine white corrosion product.
R—Gray appearance. Few spots of fine white corrosion product.
Z—Gray appearance. Few spots of fine white corrosion product.

Alloy No. XX:
Producer C—Gray appearance. Some fine white corrosion product.
D—Gray appearance.

Alloy No. XXI:
Producer D—Gray appearance. Some fine white corrosion product.
R—Gray appearance. Some fine white corrosion product.
S—Gray appearance. Some fine white corrosion product.
T—Gray appearance. Some fine white corrosion product.
Z—Gray appearance. Some fine white corrosion product.

Alloy No. XXII:
Producer C—Gray appearance. Considerable fine white corrosion product.

NEW YORK EXPOSURE

Alloy No. I:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
W—Dark discoloration. Some fine white corrosion product.

Alloy No. IV:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
W—Dark discoloration. Numerous spots of fine white corrosion product.

Alloy No. V:
Producer C—Dark discoloration. Numerous spots of fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Numerous spots of fine white corrosion product.
S—Dark discoloration. Numerous spots of fine white corrosion product.
W—Dark discoloration. Numerous spots of fine white corrosion product.

Alloy No. VII:
Producer C—Dark discoloration. Some very fine white corrosion product.
D—Dark discoloration. Few spots of fine white corrosion product.
G—Dark discoloration. Few spots of fine white corrosion product.
S—Dark discoloration. Few spots of fine white corrosion product.
W—Dark discoloration. Few spots of fine white corrosion product.

Alloy No. VIII:
Producer C—Dark discoloration. Few spots of white corrosion product.
D—Dark discoloration. Few spots of fine white corrosion product.
G—Dark discoloration. Occasional spots of white corrosion product.
S—Dark discoloration. Occasional spots of white corrosion product.
W—Dark discoloration. Some white corrosion product.

Alloy No. IX:
Producer C—Dark discoloration. Occasional spots of white corrosion product.
D—Dark discoloration. Occasional spots of fine white corrosion product.
G—Dark discoloration. Occasional spots of fine white corrosion product.
S—Dark discoloration. Occasional spots of fine white corrosion product.
W—Dark discoloration. Fine white corrosion product.

Alloy No. X:
Producer C—Dark discoloration. Occasional white corrosion product.
D—Dark discoloration. Few spots of white corrosion product.
G—Dark discoloration. Numerous spots of white corrosion product.
S—Dark discoloration. Few spots of white corrosion product.
W—Dark discoloration.

Alloy No. XI:
Producer C—Dark discoloration.
D—Dark discoloration. Numerous spots of fine white corrosion product.
G—Dark discoloration. Some spots of fine white corrosion product.
S—Dark discoloration. Occasional spots of fine white corrosion product.
W—Dark discoloration. Numerous spots of fine white corrosion product.

Alloy No. XII:
Producer C—Dark discoloration. Some spots of fine white corrosion product.
D—Dark discoloration. Numerous spots of fine white corrosion product.
G—Dark discoloration. Numerous spots of fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
W—Dark discoloration. Some fine white corrosion product.

Alloy No. XIII:
Producer C—Considerable fine white corrosion product.
D—Considerable fine white corrosion product.
R—Considerable fine white corrosion product.
T—Considerable fine white corrosion product.

Alloy No. XIV:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
R—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
T—Dark discoloration. Some fine white corrosion product.

Alloy No. XV:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
R—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
Z—Dark discoloration. Some fine white corrosion product.

Alloy No. XVI:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
Z—Dark discoloration. Considerable fine white corrosion product.

Alloy No. XVII:
Producer D—Dark discoloration. Considerable fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
T—Dark discoloration. Considerable fine white corrosion product.

Alloy No. XVIII:
Producer C—Dark discoloration. Considerable fine white corrosion product.
S—Dark discoloration. Considerable fine white corrosion product.
T—Dark discoloration. Considerable fine white corrosion product.

Alloy No. XIX:
Producer D—Dark discoloration. Some fine white corrosion product.
R—Dark discoloration. Some fine white corrosion product.
Z—Dark discoloration. Some fine white corrosion product.

Alloy No. XX:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some white corrosion product. Some pitting.

Alloy No. XXI:
Producer D—Dark discoloration. Some fine white corrosion product.
R—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Considerable fine white corrosion product.
T—Dark discoloration. Some fine white corrosion product.
Z—Dark discoloration. Considerable fine white corrosion product.

Alloy No. XXII:
Producer C—Dark discoloration. Considerable white corrosion product.

ALTOONA EXPOSURE

Alloy No. I:
Producer C—Dark discoloration. Brownish cast on top of specimens. Occasional spots of white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Few spots of white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
S—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Few spots of fine white corrosion product.

Alloy No. IV:
Producer C—Dark discoloration. Brownish cast on top of specimens. Few spots of white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
S—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.

Alloy No. V:

Producer C—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.
S—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.

Alloy No. VII:

Producer C—Dark discoloration. Brownish cast on top of specimens.
D—Dark discoloration. Brownish cast on top of specimens.
G—Dark discoloration. Brownish cast on top of specimens.
S—Dark discoloration. Brownish cast on top of specimens.
W—Dark discoloration. Brownish cast on top of specimens.

Alloy No. VIII:

Producer C—Dark discoloration. Brownish cast on top of specimens. Some white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens. Few spots of fine white corrosion product.
S—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.

Alloy No. IX:

Producer C—Dark discoloration. Brownish cast on top of specimens. Occasional spots of fine white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Occasional spots of fine white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens.
S—Dark discoloration. Brownish cast on top of specimens. Occasional spots of fine white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Occasional spots of fine white corrosion product.

Alloy No. X:

Producer C—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Numerous spots of white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens. Numerous spots of fine white corrosion product.
S—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.

Alloy No. XI:

Producer C—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
D—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens.
S—Dark discoloration. Brownish cast on top of specimens. Numerous spots of fine white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens. Some fine white corrosion product.

Alloy No. XII:
Producer C—Dark discoloration. Brownish cast on top of specimens.
D—Dark discoloration. Brownish cast on top of specimens. Few spots of fine white corrosion product.
G—Dark discoloration. Brownish cast on top of specimens.
S—Dark discoloration. Brownish cast on top of specimens. Few spots of fine white corrosion product.
W—Dark discoloration. Brownish cast on top of specimens.

Alloy No. XIII:
Producer C—Considerable fine white corrosion product.
D—Considerable fine white corrosion product.
R—Considerable fine white corrosion product.
T—Considerable fine white corrosion product.

Alloy No. XIV:
Producer C—Dark brownish cast. Some spots of fine white corrosion product.
D—Dark brownish cast. Few spots of fine white corrosion product.
R—Dark brownish cast. Few spots of fine white corrosion product.
S—Dark brownish cast. Few spots of fine white corrosion product.
T—Dark brownish cast. Few spots of fine white corrosion product.

Alloy No. XV:
Producer C—Dark brownish cast.
D—Dark brownish cast. Few spots of fine white corrosion product.
R—Dark brownish cast.
S—Dark brownish cast.
Z—Dark brownish cast.

Alloy No. XVI:
Producer C—Dark brownish cast. Few spots of fine white corrosion product.
D—Dark brownish cast.
S—Dark brownish cast. Few spots of fine white corrosion product.
Z—Dark brownish cast.

Alloy No. XVII:
Producer D—Dark brownish cast.
S—Dark brownish cast.
T—Dark brownish cast.

Alloy No. XVIII:
Producer C—Dark brownish cast.
S—Dark brownish cast.
T—Dark brownish cast.

Alloy No. XIX:
Producer D—Dark brownish cast.
R—Dark brownish cast.
Z—Dark brownish cast. Few spots of fine white corrosion product.

Alloy No. XX:
Producer C—Dark brownish cast. Some fine white corrosion product. Some pitting.
D—Dark brownish cast. Some fine white corrosion product. Some pitting.

Alloy No. XXI:
Producer D—Dark brownish cast.
R—Dark brownish cast. Few spots of fine white corrosion product.
S—Dark brownish cast. Few spots of fine white corrosion product.
T—Dark brownish cast. Few spots of fine white corrosion product.
Z—Dark brownish cast. Few spots of fine white corrosion product.

Alloy No. XXII:
Producer C—Dark brownish cast. Considerable fine white corrosion product.

STATE COLLEGE EXPOSURE

Alloy No. I:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Retains almost original metallic luster.
S—Slightly gray in appearance.
W—Retains almost original metallic luster.

Alloy No. IV:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Retains almost original metallic luster.
S—Retains almost original metallic luster.
W—Retains almost original metallic luster.

Alloy No. V:
Producer C—Retains almost original metallic luster.
D—Somewhat gray in appearance.
G—Retains almost original metallic luster.
S—Retains almost original metallic luster.
W—Retains almost original metallic luster.

Alloy No. VII:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Retains almost original metallic luster.
S—Somewhat gray in appearance.
W—Somewhat gray in appearance.

Alloy No. VIII:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Retains almost original metallic luster.
S—Retains almost original metallic luster.
W—Retains almost original metallic luster.

Alloy No. IX:
Producer C—Somewhat gray in appearance.
D—Somewhat gray in appearance.
G—Somewhat gray in appearance.
S—Somewhat gray in appearance.
W—Retains almost original metallic luster.

Alloy No. X:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Somewhat gray in appearance.
S—Somewhat gray in appearance.
W—Retains almost original metallic luster.

Alloy No. XI:
Producer C—Retains almost original metallic luster.
D—Retains almost original metallic luster.
G—Retains almost original metallic luster.
S—Retains almost original metallic luster.
W—Retains almost original metallic luster.

Alloy No. XII:
Producer C—Somewhat gray in appearance.
D—Somewhat gray in appearance.
G—Somewhat gray in appearance.
S—Quite dark in appearance.
W—Somewhat gray in appearance.

Alloy No. XIII:
Producer C—Some white corrosion product.
D—Some fine white corrosion product.
R—Considerable fine white corrosion product.
T—Considerable fine white corrosion product.

Alloy No. XIV:
Producer C—Some fine white corrosion product.
D—Few spots of fine white corrosion product.
R—Few spots of fine white corrosion product.
S—Few spots of fine white corrosion product.
T—Few spots of fine white corrosion product.

Alloy No. XV:
Producer C—Few spots of fine white corrosion product.
D—Gray appearance.
R—Gray appearance. Few spots of white corrosion product.
S—Gray appearance. Few spots of white corrosion product.
Z—Few white spots of corrosion product.

Alloy No. XVI:
Producer C—Gray appearance. Few spots of fine white corrosion product.
D—Gray appearance. Few spots of fine white corrosion product.
S—Gray appearance. Few spots of fine white corrosion product.
Z—Gray appearance. Few spots of fine white corrosion product.

Alloy No. XVII:
Producer D—Gray appearance. Few spots of fine white corrosion product.
S—Gray appearance. Few spots of fine white corrosion product.
T—Some fine white corrosion product.

Alloy No. XVIII:
Producer C—Considerable fine white corrosion product.
S—Considerable fine white corrosion product.
T—Some fine white corrosion product.

Alloy No. XIX:
Producer D—Dark appearance. Few spots of fine white corrosion product.
R—Some fine white corrosion product.
Z—Some fine white corrosion product.

Alloy No. XX:
Producer C—Some fine white corrosion product. Some pitting.
D—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XXI:
Producer D—Some fine white corrosion product.
R—Few spots of fine white corrosion product.
S—Dark appearance.
T—Dark appearance. Few spots of fine white corrosion product.
Z—Considerable fine white corrosion product.

Alloy No. XXII:
Producer C—Considerable fine white corrosion product.

ROCHESTER EXPOSURE

Alloy No. I:
Producer C—No photographs taken.
D—Dark discoloration. Numerous spots of fine white corrosion product.
G—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Numerous spots of fine white corrosion product.
W—Dark discoloration. Numerous spots of fine white corrosion product.

Alloy No. IV:
Producer C—Dark discoloration. Numerous spots of fine white corrosion product.
D—Dark discoloration. Numerous spots of fine white corrosion product.
G—Dark discoloration. Numerous spots of fine white corrosion product.
S—Dark discoloration. Numerous spots of fine white corrosion product.
W—Dark discoloration. Numerous spots of white corrosion product.

Alloy No. V:
Producer C—Dark discoloration. Numerous spots of white corrosion product.
D—Dark discoloration. Numerous spots of white corrosion product.
G—Dark discoloration. Numerous spots of white corrosion product.
S—Dark discoloration. Numerous spots of white corrosion product.
W—Dark discoloration. Numerous spots of white corrosion product.

Alloy No. VII:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Some fine white corrosion product.
S—Dark discoloration. Some fine white corrosion product.
W—Dark discoloration. Some fine white corrosion product.

Alloy No. VIII:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Considerable fine white corrosion product.
S—Dark discoloration. Considerable fine white corrosion product.
W—Dark discoloration. Considerable fine white corrosion product.

Alloy No. IX:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some fine white corrosion product.
G—Dark discoloration. Considerable fine white corrosion product.
S—Dark discoloration. Considerable fine white corrosion product.
W—Dark discoloration. Considerable fine white corrosion product.

Alloy No. X:
Producer C—Dark discoloration. Some white corrosion product.
D—Dark discoloration. Considerable fine white corrosion product.
G—No photograph taken.
S—Dark discoloration. Considerable fine white corrosion product.
W—Dark discoloration. Some fine white corrosion product.

Alloy No. XI:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some white corrosion product.
G—Dark discoloration. Some white corrosion product.
S—Dark discoloration. Some white corrosion product.
W—Dark discoloration. Few white corrosion product.

Alloy No. XII:
Producer C—Dark discoloration. Some fine white corrosion product.
D—Dark discoloration. Some white corrosion product.
G—Dark discoloration. Considerable fine white corrosion product.
S—No photographs taken.
W—No photographs taken.

Alloy No. XIII:
Producer C
D
R
T
Specimens stolen from exposure rack.

Alloy No. XIV:
Producer C
D
R
S
T
Specimens stolen from exposure rack.

Alloy No. XV:
Producer C—Dark appearance. Few spots of fine white corrosion product.
D—Dark appearance. Few spots of fine white corrosion product.
R—Dark appearance. Few spots of fine white corrosion product.
S—Dark appearance. Few spots of fine white corrosion product.
Z—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XVI:
Producer C—Dark appearance. Considerable fine white corrosion product.
D—Dark appearance. Few spots of fine white corrosion product.
S—Dark appearance. Few spots of fine white corrosion product.
Z—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XVII:
Producer D—Dark appearance. Few spots of fine white corrosion product.
S—Dark appearance. Few spots of fine white corrosion product.
T—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XVIII:
Producer C—Dark appearance. Some fine white corrosion product.
S—Dark appearance. Considerable fine white corrosion product.
T—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XIX:
Producer D—Few spots of fine white corrosion product.
R—Dark appearance. Some fine white corrosion product.
Z—Dark appearance. Some fine white corrosion product.

Alloy No. XX:
Producer C—Dark appearance. Small corrosion blisters.
D—Dark appearance. Small corrosion blisters.

Alloy No. XXI:
Producer D—Dark appearance. Few spots of fine white corrosion product.
R—Dark appearance.
S—Dark appearance. Few spots of fine white corrosion product.
T—Dark appearance.
Z—Dark appearance. Few spots of fine white corrosion product.

Alloy No. XXII:
Producer C—Specimens stolen from exposure rack.

DISCUSSION

Mr. A. J. Field.[1]—There is one brief comment I should like to make on the aluminum alloys covered in this report. As stated in the report, there are small changes in properties which probably have been caused by age hardening and are to be seen by studying the test results on the indoor exposed specimens only. In connection with this age hardening, which is of only very minor magnitude, it is of special interest to examine whether the age hardening is likely to be progressive or takes place in the early stages only. Some information on this point can be gained by comparing the results after 5 yr. indoor exposure with those after 1 yr. indoor exposure, which were published by the committee in 1932.[2] It will be found, considering only those specimens of acceptable chemical analysis, that the changes between the 1-yr. and 5-yr. indoor properties are very much less in magnitude than between the original and 5-yr. properties, and in many cases are nil. A safe conclusion from this is that the greater part of the small age hardening that has taken place was completed in 1 yr. and that practically no further hardening has taken place between 1 and 5 yr.

(*By letter.*)—A consideration of the report of Subcommittee V of Committee B-6 indicates that it may be helpful to have the committee's extensive data on aluminum die-cast alloys available in a compressed and selected form, so as to render the conclusions of the subcommittee more readily confirmable by an examination of the figures, and to provide a broad basis of study of the behavior of the different alloys by averaging such variations as those due to different producers. In comparing the various alloys, it seems reasonable that only those specimens of which the composition comes close to allowable limits should be included for study.

With the above objects in view, the accompanying Table I of average properties is presented. This table has been compiled only for those specimens of "acceptable" chemical analysis, as given in a previous paper by the writer.[3] The table covers average physical properties for each alloy after 5-yr. outdoor and 5-yr. indoor exposure, the figures for which have been derived from the results given in the present report. Average properties after 1-yr. indoor exposure are also included, the figures for which are derived from results previously published by the committee.[2] Also included in Table I are average "original" properties, which are not derived from the committee's present report, but which have been copied from a previous paper by the writer.[1] The "original" tensile and elongation properties here included were obtained by averaging the results of 6 testing laboratories for all specimens extending over an interval of time averaging about 7 months from the dates of casting, whereas the "as cast" figures given in the committee's report include results from 1 to 4 testing laboratories for each set of specimens extending over a time of 1 to 3 months after casting. A close study of individual results has shown that no significant difference in tensile or elongation results is introduced by the writer's selection of "original" values, but rather that it is preferable to use the broader base for the averages, which has the additional advantage of giving impact values for all specimens. The "original" impact values in Table I are derived from 3 testing laboratories for all specimens at an average interval of about 6 months after casting, the results from one laboratory being uniformly rather higher than from the other two, so that the "original" average impact values may be slightly on the high side.

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[1] Technical Representative, Arthur Seligman and Co., Inc., New York City.

[2] Report of Committee B-6, Appendix: Table of Physical Properties of Aluminum-Base Die-Casting Alloy Specimens After 1-Year Indoor Exposure, *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 275 (1932).

[3] A. J. Field, "The Physical Properties of Aluminium-Base Die-Casting Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 285 (1932).

TABLE I.—AVERAGE PHYSICAL PROPERTIES OF ¼-IN. DIAMETER DIE-CAST TEST BARS (OF "ACCEPTABLE" CHEMICAL ANALYSIS ONLY).

Alloy	Nominal Composition, per cent			Tensile Strength, lb. per sq. in.				Elongation in 2 in., per cent				Impact Strength, ft-lb.			
	Copper	Silicon	Nickel	Original	1 yr. In-door	5 yr. In-door	5 yr. Out-door	Original	1 yr. In-door	5 yr. In-door	5 yr. Out-door	Original	1 yr. In-door	5 yr. In-door	5 yr. Out-door
No. I	4	...	...	30 150	30 960	31 330	30 570	4.4	4.1	3.5	3.9	6.9	5.6	5.5	5.0
No. II	10	...	...	34 720	36 420	37 060	.....	1.8	1.6	1.5	...	3.5	2.6	2.6	...
No. III	14	...	...	38 760	40 370	40 760	.....	1.0	0.8	0.8	...	1.9	1.3	1.2	...
No. IV	...	5	...	28 760	28 850	29 000	29 190	3.1	3.4	3.4	3.3	5.4	4.4	4.5	4.3
No. V	...	12	...	32 560	33 530	33 690	31 790	1.5	1.6	1.7	1.3	2.3	2.0	2.0	1.8
No. VI	2	3	...	29 700	31 160	31 450	.....	3.6	3.6	3.4	...	5.5	4.6	4.5	...
No. VII	4	5	...	33 120	34 350	34 650	34 050	1.9	1.9	1.7	1.9	2.7	2.0	1.9	1.7
No. VIII	1.5	1	2.25	29 070	29 540	30 240	29 050	3.7	3.7	3.6	3.4	4.3	4.0	3.8	3.7
No. IX	4	1.75	4	31 560	33 160	33 120	32 450	1.7	1.6	1.5	1.4	2.3	1.9	1.8	1.6
No. X	...	2	5	27 870	28 000	27 800	27 870	2.1	2.2	2.2	2.1	2.9	2.5	2.5	2.4
No. XI	2	8	...	32 320	33 520	33 760	33 290	1.7	1.8	1.8	1.5	3.0	2.5	2.4	2.1
No. XII	8	1.5	...	34 410	36 600	35 270	34 730	1.6	1.5	1.4	1.3	3.2	2.2	2.3	1.9

NOTE.—Properties after 1 yr. exposure, average of 4 locations.
Properties after 5 yr. indoor exposure, average of 4 locations.
Properties after 5 yr. outdoor exposure, average of 5 locations.

An examination of Table I will more readily enable the subcommittee's conclusions to be confirmed, and will show that such changes in physical properties as have taken place in 5 yr. indoor and outdoor exposure are very small. It can also be seen that the individual alloys tested differ but little from one another in their high resistance to the exposures.

Attention is drawn to the 1 yr. indoor and 5 yr. indoor exposure results, an examination of which justifies the conclusion that such age-hardening as has taken place is of no important magnitude in any alloy, and that all alloys are practically stable in properties after 1 yr. indoor exposure.

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[1] *Loc. cit.*

The effects of the various 5-yr. exposure localities cannot be seen in Table I. An examination of the committee's figures to determine the effects of the different localities on the properties of the different alloys shows no great special effect of any locality on any individual alloy. It therefore seems justifiable and of interest to examine the mean effect of each locality on all alloys. For this reason the accompanying Tables II and III are presented, in which are shown the mean tensile and impact strengths of all alloys at each outdoor and each indoor locality respectively, the averages being derived from specimens of "acceptable" analysis only. The results confirm the subcommittee's comments and show that there is no very marked difference in the effects of any of the outdoor localities in 5 yr., and the same remark applies to the indoor localities.

TABLE II.—EFFECT OF LOCALITY ON MEAN PROPERTIES OF NINE DIFFERENT ALLOYS AFTER 5 YR. OUTDOOR EXPOSURE.

	TENSILE STRENGTH, LB. PER SQ. IN.	IMPACT STRENGTH, FT-LB.
Key West, Fla	31 640	2.49
Sandy Hook, N. J	31 090	2.89
Rochester, N. Y	.....	2.84
Altoona, Pa	31 420	2.70
New York, N. Y	31 170	2.85
State College, Pa	31 900	2.81

TABLE III.—EFFECT OF LOCALITY ON MEAN PROPERTIES OF TWELVE DIFFERENT ALLOYS AFTER 5 YR. INDOOR EXPOSURE.

	TENSILE STRENGTH, LB. PER SQ. IN.	IMPACT STRENGTH, FT-LB.
Coco Solo, C. Z	33 700	2.80
Cambridge, Mass	32 810	3.06
New Kensington, Pa	33 360	2.76
Hanover, N. Mex	33 180	3.13

REPORT OF COMMITTEE C-1
ON
CEMENT

The results of the year's activities of Committee C-1 on Cement can be best evaluated from the fact that it has submitted for action by Committee E-10 on Standards one proposed tentative specification and three tentative methods of test. It has further continued active work along other lines which should shortly lead to the promulgation of standards. Briefly, this work has been confined to test requirements and methods for high-early-strength cements, short methods for the determination of the magnesia in cements, methods for indicating volume changes during hardening, and the continuation of the services of the Cement Reference Laboratory in calibrating testing equipment and in demonstrating to laboratory operators the proper procedure to be used in carrying out cement testing according to A.S.T.M. Standards.

High-Early-Strength Cement:

The Sponsoring Committee on High-Early-Strength Cements (M. A. Swayze, chairman) has been carrying out an investigation of all the cements (totaling 33) of that type now available in our markets. Four laboratories have cooperated in the work in which special features were the determination of the fineness by the No. 325 sieve and the specific surface by the Wagner turbidimeter or hydrometer, the making and testing of the usual standard sand briquets, plastic mortar cubes according to the new A.S.T.M. Tentative Method of Test for Compressive Strength of Portland Cement Mortars (C 109 – 34 T), and 6 by 12-in. concrete cylinders. The purpose of this study was primarily to compare the results of the mortar cubes with briquets and concrete, as there has been evidenced a considerable demand for a compression test specimen of mortar rather than the commonly used tension specimen. The data are now in the hands of the committee as a whole.

The committee at its spring meeting after giving consideration to the present status of the Tentative Specifications for High-Early-Strength Portland Cement (C 74 – 30 T), voted to submit to letter ballot of the committee the question of recommending their adoption as standard with but one revision, deleting the fineness requirements. The results of this letter ballot were favorable. The committee is therefore recommending that with this revision these tentative specifications be submitted to the Society for adoption as standard.[1]

Although these specifications cover only high-early-strength cements of the true portland type, the committee has not lost sight of those high-early-strength cements which are mixtures of portland cement and small quantities of other materials. It is believed that within a short time specifications will be available covering these.

Masonry Cement:

The Sponsoring Committee on Masonry Cement (H. D. Baylor, chairman) has given consideration to the Tentative Specifications and Tests for Masonry Cement (C 91 – 32 T) for which it is responsible. Notwithstanding the great interest by various groups in masonry cements, the committee has not received much in the way of comments as a result of promulgating these tentative specifications. It consequently addressed a questionnaire to all those known manufacturers of this commodity, asking among other things, their attitude towards withdrawing these Tentative Specifications or continuing them "as is" pending further study, or revising them along lines which they were to suggest in replying to the questionnaire. Unfortunately, no very constructive suggestions were received regarding the nature of future studies, but it was very evident that the manufacturers did not desire having the tentative standard withdrawn. Hence, the committee is recommending that Specifications C 91 – 32 T be continued as tentative for another year.

Chemical Analysis:

Although the Working Committee on Methods of Chemical Analysis (W. C. Hanna, chairman) completed during the year the preparation of the recently issued Tentative Method of Chemical Analysis of Portland Cement (C 114 – 34 T),[2] it has actively continued its work. Where specifications do not require a complete chemical analysis but place limits upon the amount of magnesia allowable, it is very desirable that a shorter method be available than that contained in the present Standard Methods of Sampling and Testing Portland Cement (C 77 – 32). The working committee has conducted a comparative investigation in a group of laboratories covering several quick methods and the present Tentative Method C 114 – 34 T. The results indicate that possibly two of the shorter methods may be adequate. They appear both precise and accurate, as may be noted in the report appended hereto, wherein are presented briefly the results of this investigation. However, the committee is not ready at this time to make any recommendations[1] and is now conducting a second cooperative study using two cements and participated in by 24 laboratories.

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[1] This recommendation failed to receive the necessary two-thirds vote at the session of the annual meeting, see Summary of Proceedings, p. 24. The specifications are accordingly being continued as tentative.

[2] The method in its latest form appears on p. 766.

It has also inaugurated work covering the determination of manganese oxide and ferrous oxide in cements. The presence of these oxides in any quantity very materially affects the calculations of the amounts of the four major compounds assumed to be present in portland cement. Hence, the determination of these becomes a matter of much moment.

Low-Heat and Blended Cements:

It is with much regret that the committee cannot announce more than progress in its work on low-heat and blended cements. While it is true that the agitation regarding true low-heat cements has somewhat subsided, the opposite is the case with blended cements. It is believed, however, that during the coming year something more than progress will be achieved in these two activities.

Volume Change and Soundness:

The Working Committee on Volume Change and Soundness of Portland Cement (H. F. Gonnerman, chairman) which has been assigned these problems has not lost sight of the importance of further work towards developing better methods to determine volume change and soundness. But while it seems that the early disintegration of cement products or test specimens, due to inadequate manufacturing procedure, has become a thing of the past and the test method has become almost unnecessary, there remains much concern over the change in volume due to hardening and to cycles of wetting and drying. What work has so far been carried out by the working committee has not yet yielded results which might be used as a basis for developing an acceptance test. The question is being actively studied.

Plasticity:

The Working Committee on Plasticity (C. H. Scholer, chairman) has given some thought to the possibility of applying certain procedures used at the National Bureau of Standards in its study of masonry cements as a method for evaluating the relative plasticity of cements. This method involves a change in working qualities of mortars after being subjected to the withdrawal of water by an absorptive base. A questionnaire was distributed to a number of laboratories studying this property and elicited some interesting comments, but did not lead to any information which might be used in developing a test program.

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[1] Subsequent to the annual meeting Committee C-1 presented to the Society as tentative two quick methods for the determination of magnesia content in portland cement, see p. 235.

Cement Reference Laboratory:

A brief report of the activities of this laboratory, maintained at the National Bureau of Standards by the committee, is appended hereto. Of particular interest is a tabulation showing the results of the calibration of equipment on the several inspection tours, which now total four. This shows the value of this work most concisely and conclusively and it further shows the spirit in which the public has accepted the efforts of the committee. Such a marked increase in acceptable equipment has been brought about only by the ready and prompt acquiescence of those maintaining testing laboratories in the inspection results. The suggested replacement or readjustment of faulty equipment has in many cases entailed an expenditure of considerable funds, but it seems that those who have made such expenditures have been very highly pleased with the improvement in their laboratories. With the adoption of some of the new tentative methods, such as those involving compression specimens, the work of the Cement Reference Laboratory will have to be expanded to take care of the equipment used in such testing. This is being considered by the subcommittee concerned with this activity.

New Tentative Standards:

During the year Committee C-1 presented to the Society, through Committee E-10 on Standards, four proposed standards for publication as tentative. Two of these, the Tentative Method of Chemical Analysis of Portland Cement (C 114 - 34 T),[1] and Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 - 34 T),[1] were formally accepted by Committee E-10 on December 27, 1934 and have now been issued as tentative.[2] Approval of the other two proposed standards, namely, Specifications for Sulfate-Resistant Portland Cement, and Methods for Sampling and Testing Sulfate-Resistant Portland Cement, was withheld pending the receipt of more supporting data. These are being given further thought by Committee C-1. The Tentative Methods C 114 - 34 T and C 115 - 34 T have been published so recently that no comments have been received; consequently it is being recommended that they be continued as tentative for the coming year.

Plastic Mortar:

It is also recommended that the Tentative Method of Test for Compressive Strength of Portland-Cement Mortars (C 109 - 34 T), remain as tentative for another year. This method is being used not only for further study by the committee, but is also being used in purchase specifications in several large concreting operations; among others, by the Tennessee Valley Authority in a recent purchase of 6,500,000 barrels of cement and in the purchase of 1,200,000 barrels by the United States Engineer Office for the Tygart River Reservoir Dam. Several laboratories are cooperating also in studying such questions as the effect on the strength of variation in the grading of the sand, of using a variable instead of a fixed amount of water, of using non-sealed instead of sealed molds, speed of testing, etc. Valuable information should soon be available which will be of use to the committee in considering the adoption of this method as standard.

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[1] These methods in their latest form appear on pp. 776 and 777.

[2] In submitting these tentative methods to Committee E-10 on Standards, Committee C-1 reported the following results of the letter ballot vote of a total of 65 ballots returned from a committee membership of 73: Tentative Method of Chemical Analysis of Portland Cement (C 114 - 34 T), 55 affirmative, 1 negative, and 9 marked their ballots "not voting"; Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 - 34 T), 51 affirmative, 2 negative, and 12 marked their ballots "not voting."

RECOMMENDATIONS AFFECTING STANDARDS

The committee proposes that the fineness requirement in Section 3 of the Tentative Specifications for High-Early-Strength Portland Cement (C 74 – 30 T) be deleted and recommends that the specifications as thus revised be referred to letter ballot of the Society for adoption as standard.[1] This recommendation has been submitted to letter ballot of the committee, which consists of 73 members; 73 members returned their ballots, of whom 53⅔ have voted affirmatively, 11⅓ negatively and 7 marked their ballots "not voting."

This report has been submitted to letter ballot of the committee which consists of 73 members; 61 members returned their ballots, of whom 60 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

G. A. SAEGER,
Secretary.

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[1] This recommendation failed to receive the necessary two-thirds vote at the session of the annual meeting, see Summary of Proceedings, p. 24. The specifications are accordingly being continued as tentative.

REPORT OF THE WORKING COMMITTEE ON METHODS OF CHEMICAL ANALYSIS

REPORT OF STUDY OF A QUICK METHOD FOR DETERMINING MAGNESIA IN CEMENT

There is presented in Table I a digest of a preliminary study of the results obtained in analyzing several cements for magnesia by three methods. Two of these methods were developed by their authors (Fred P. Diener[1] and John C. Redmond[2]) as a means of quickly obtaining the final result, when compared with the time necessary to make the determination using the procedures described in the Tentative Methods of Chemical Analysis of Portland Cement (C 114 - 34 T).[3] Since these newer methods are not generally known they are presented herewith.[4]

TABLE I.—PERCENTAGE MAGNESIA CONTENT OF PORTLAND CEMENTS AS DETERMINED BY DIFFERENT METHODS.

Method I: U. S. Bureau of Reclamation Specifications 599-D and 566 for Boulder Dam.
Method III: 8-Hydroxyquinoline Method of J. C. Redmond.
Method IV: Volumetric Method of F. P. Diener.

Laboratory	Cement A[a]			Cement B			Cement C			Cement D		
	Method I	Method III	Method IV	Method I	Method III	Method IV	Method I	Method III	Method IV	Method I	Method III	Method IV
No. 1	4.04	4.14	3.93	3.41	3.58	3.34	5.31	5.34	5.34	5.43	5.40	5.47
No. 2	4.08	4.22	4.16	3.45	3.46	3.44	5.37	5.16	5.36	5.55	5.18	5.36
No. 3	4.09	4.01	4.14	3.59	3.41	3.53	5.38	5.19	5.35	5.53	5.38	5.53
No. 4	4.10	3.92	....	3.51	3.24	....	5.51	5.27	....	5.66	5.43	....
No. 5	4.27	4.04	3.80	3.63	3.42	3.46	5.58	5.15	5.10	5.62	5.24	5.34
No. 6	4.46	4.11	4.75	3.79	3.56	3.90	5.73	5.45	5.70	5.89	5.55	6.15
No. 7	4.04	3.95	....	3.39	3.37	....	5.23	5.10	....	5.42	5.31	....
No. 8	4.24	....	....	3.58	....	....	5.59	....	....	5.72	....	....
No. 9	4.20	4.15	4.50	3.36	3.47	3.50	(4.80)	(4.64)	5.00	5.12	4.98	5.20
No. 10	4.47	(4.59)	4.38	3.77	(3.94)	3.98	5.68	(6.02)	5.56	5.92	(6.12)	5.95
Averages[b]	4.20	4.07	4.24	3.55	3.44	3.59	5.49	5.24	5.34	5.59	5.31	5.57

[a] Careful analysis of Cement A under the supervision of G. E. F. Lundell, National Bureau of Standards, showed a magnesia content of 4.07 per cent. This determination was not made by Method I.

[b] Averages are the mean of the results reported by laboratories, omitting values in parentheses.

Since the methods were entirely new to many analysts, another cooperative investigation is under way, which is being participated in by 24 laboratories. The data so far obtained indicate great likelihood that a very satisfactory quick method may be obtained.

Respectfully submitted on behalf of the working committee,

W. C. HANNA,
Chairman.

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[1] Assistant Chief Chemist, Northampton Plant, Universal Atlas Cement Co., Northampton, Pa.

[2] Battelle Memorial Inst., Columbus, Ohio; formerly of National Bureau of Standards, Washington, D. C.

[3] Accepted for publication as tentative by Committee E-10 on Standards, December 27, 1934; see p. 766.

[4] Subsequent to the submission of this report, these two methods were presented by Committee C-1 to the Society through Committee E-10 on Standards at a meeting on August 22, 1935, and were accepted for inclusion in the Tentative Method C 114 as alternate, more rapid methods for the determination of magnesia when magnesia alone is to be determined, with the understanding, however, that in case of dispute the results obtained in accordance with Section 11 of the Standard Methods of Sampling and Testing Portland Cement (A.S.T.M. Designation: C 77) shall govern. Since these rapid methods appear in full in the revised Tentative Method C 114 - 35 T, see p. 766, they have not been included in this report.—ED.

REPORT OF SUBCOMMITTEE ON CEMENT REFERENCE LABORATORY

(Period April 1, 1934, to March 31, 1935)

The fourth tour of inspection among the cement laboratories of the country was begun just a few days before the end of the period covered by the Reference Laboratory's report as presented in the 1934 report of Committee C-1.[1] Of the 229 laboratories which have requested inspection to be made in this tour, inspections of 143 or about two thirds of this current tour has been completed.

There is still in effect the rule of the U. S. Bureau of Public Roads requiring Reference Laboratory inspection at those cement testing laboratories which make acceptance tests of cement for Federal Aid projects. There have already been sent to the Bureau of Public Roads, during the work of the fourth tour, copies of a large number of reports covering the inspections at various highway and commercial testing laboratories.

In the last annual report of Committee C-1[1] there was presented a table which indicated a gradual increase in the percentage of cement testing apparatus which complied with the current A.S.T.M. specifications. Table I of this report shows the quantity of apparatus tested during the fourth inspection tour to date, and the percentage of such apparatus which was in accordance with specification requirements. Again there appears progressive improvement.

The Reference Laboratory prepared and distributed fineness samples of four cements and carried out a series of comparative turbidimeter tests in cooperation with 30 laboratories. The purpose of this series of tests was to study the possibilities of a proposed method of calibrating the Wagner turbidimeter. Results showed that with the new method of calibration the cooperating laboratories could secure more uniform results than with the method previously in use. The new method of calibration has since been incorporated in the A.S.T.M. Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T).[2] As a result of studies made some months ago on the timing burette used with the Wagner turbidimeter, there was prepared a specification for an improved burette. This likewise has been included in the Tentative Method C 115 – 34 T.

It was found necessary to improve the method of packing the standard sample used for calibrating the turbidimeter. The Reference Laboratory devoted considerable time to improving the container for this sample.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 34, Part I, p. 361 (1934).

[2] See p. 777.

Recently, some time has been devoted to a study of methods of determining or comparing the consistencies of mortars. Thus far, the work has not progressed enough to warrant a progress report. Some study has also been made of the possibilities of using the Wagner turbidimeter for making fineness determinations on the sand specified for the plastic mortar cubes. This work is prompted by questions as to the probable differences which might be found in the sieves, which may comply with the standard specifications and yet differ among themselves in actual sieving behavior.

During the winter considerable time has been spent by the inspectors in tabulating those portions of old inspection reports relating to methods observed in the field. The purpose was to provide such statistics as might indicate what degree of improvement, if any, had been achieved during the course of the work. This study has just been completed and is now summarized in Table II.

TABLE I.—COMPARISON OF APPARATUS APPROVED DURING LABORATORY INSPECTION TOURS.

Apparatus	Fourth Tour, to Date[a]		Third Tour	Second Tour	First Tour
	Pieces Tested	Approved, per cent	Approved, per cent	Approved, per cent	Approved, per cent
Steam chests	127	92	78	63	48
Balances for mixes	176	89	86	68	74
Balances for fineness	124[b]	92	76	49	33
Tensile machines	142	87	80	62	43
Vicat apparatus	166	82	80	51	30
Gillmore needles (pairs)	166	95	89	61	58
Briquet molds	5338	92	92	80	67
Graduates	344	93	94	92	84
Weights for mixes	1866	99.7	98	93	97
Weights for fineness	1712	99.6	98	95	95

[a] Covers completed inspections of 143 laboratories out of the total of 229 laboratories which requested inspection.

[b] This figure includes balances actually tested during the inspection and does not include 9 balances in laboratories which were not tested because of unsuitable type. Four laboratories were without fineness balances. Ten laboratories used chemical analytical balances for fineness tests and three laboratories used balances approved when tested in other laboratories.

It was not feasible to present the status of observed methods of test in as brief and definite a form as was used in the tables describing the condition of apparatus. However, it appeared that some helpful information might be obtained by listing under the principal items of test procedure the various important minor details, and then listing opposite each of the subdivisions the percentage of laboratories which demonstrated that portion of the method in accordance with specification requirements. It is not meant that these subdivisions have the same relative weight.

Table II and Fig. 1 are quite self-explanatory. During the progress of the work there were changes in specifications, but nevertheless the figures are indicative of uniformity of practice. It will be observed that in nearly all cases there was progressive improvement during the period of inspection. It will also be observed that during the portion of the fourth tour which has been thus far completed, those laboratories which have had at least one

TABLE II.—PERCENTAGE OF EACH TEST METHOD DETAIL WHICH, IN DEMONSTRATIONS AND ANSWERS, WAS FOUND IN ACCORDANCE WITH REQUIREMENTS.

Test	First Tour	Second Tour			Third Tour			Fourth Tour[a]		
	No Prior Inspection	No Prior Inspection	One Prior Inspection	All	No Prior Inspection	At Least One Prior Inspection	All	No Prior Inspection	At Least One Prior Inspection	All
A. Treatment of sample:										
1. Passed through No. 20 sieve	64	55	79	68	63	90	86	72	87	86
2. Air-tight storage containers	65	48	80	67	73	80	79	72	88	87
B. Fineness (hand sieving test):										
1. Sieves calibrated	82	73	95	86	89	96	97	86	98	97
2. Size of sample	87	94	95	94	95	98	98	100	100	100
3. Preliminary sieving	86	92	91	91	90	95	94	100	98	98
4. Sieving for end point	56	64	87	78	67	86	84	83	92	91
5. Timing for end point	48	62	76	70	67	87	85	83	90	90
6. End point	55	60	72	67	67	80	79	83	88	89
7. Pan and cover for final sieving[b]	57	64	63	63	67	80	78	83	76	77
C. Normal consistency:										
1. Temperature of mixing water	37	23	44	35	30	55	52	67	55	56
2. Size of batch	95	98	100	99	92	99	98	100	99	99
3. Turning cement into water	94	85	96	91	73	91	88	50	92	90
4. Absorption period (initial point)	31	47	80	65	62	91	87	67	92	89
5. Absorption period (length)	59	69	93	82	77	93	91	67	94	93
6. Mixing time[c]	62	62	89	77	58	78	75	33	86	84
7. Manner of mixing	84	70	91	82	85	94	93	83	93	93
8. Filling mold	51	54	62	58	48	80	76	83	86	85
9. Time between mixing and plunger release[d]	38	21	38	31	28	70	65	50	74	73
10. Penetration time	73	78	96	88	84	99	97	83	95	94
D. Gillmore setting time test:										
1. Shaping pat	69	61	67	65	46	74	70	57	77	76
2. Finishing top surface	41	43	64	55	58	74	71	57	79	78
3. Dimensions of pat	30	46	49	48	23	64	59	43	44	44
E. Tension test:										
1. Size of batch	75	82	93	89	85	96	94	100	100	100
2. Mixing dry cement and sand	97	100	100	100	100	99	100	100	100	100
3. Turning materials into water	96	87	90	94	81	95	93	83	98	98
4. Absorption period (initial point)	32	46	77	64	54	90	86	83	91	90
5. Absorption period (length)	56	66	91	80	65	93	90	83	94	93
6. Mixing time	84	48	90	72	58	81	78	67	88	87
7. Slab or auxiliary plate dry	88	75	82	79	68	93	90	100	93	93
8. Filling mold	63	72	86	80	81	96	94	100	98	98
9. Compacting mortar	58	60	80	71	69	81	80	67	92	91
10. Troweling	58	48	62	56	46	60	62	83	68	69
F. Soundness:										
1. Pats correctly steamed	90	98	96	97	96	98	98	100	100	100
2. Chest at 98 C. when test began	40	70	68	69	48	89	82	86	95	95
Number of demonstrations forming bases for computations. (Varies for different details)	140 - 200	85 - 114	128 - 146	213 - 256	21 - 27	167 - 182	188 - 209	6 - 7	109 - 124	115 - 131

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[a] Fourth inspection tour now in progress.

[b] Pan and cover not required by specifications until early part of third tour.

[c] Mixing time of "at least one minute" was specified until revision in early part of third tour required $1\frac{1}{2}$ minutes.

[d] The length of this interval was not made a part of specifications until early part of third tour.

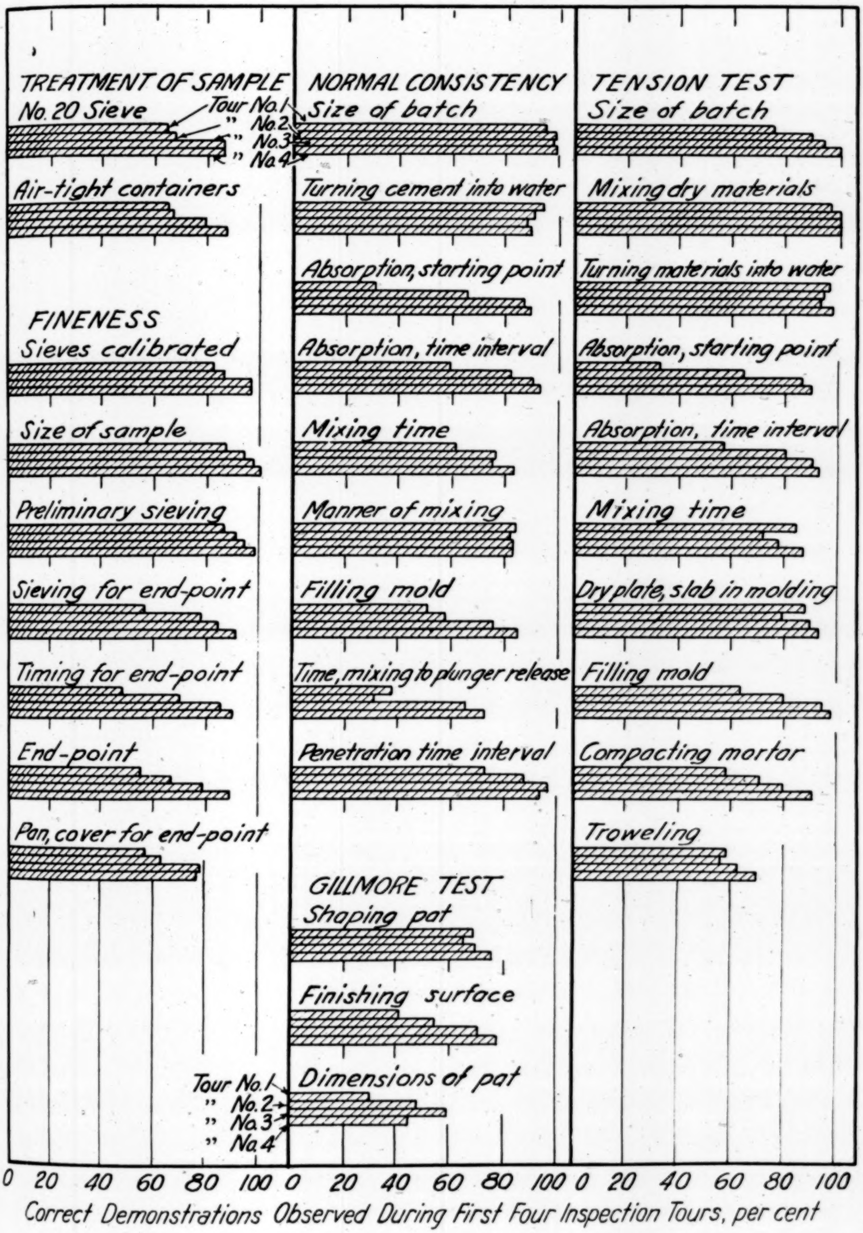

FIG. 1.—Comparison of Conformance with Standard Methods as Observed in the Demonstrations Offered by the Various Laboratories During the Four Inspection Tours.

prior inspection adhered to specification details more closely than those which were inspected for the first time.

In accordance with instructions received from the Executive Committee of Committee C-1 at the February meeting, this subcommittee is now considering certain subjects suggested during the past year as meriting study by the Reference Laboratory. Among the subjects are the following: study of methods for measuring the consistency of plastic mortars; comparative strength tests on samples of cements distributed by the Reference Laboratory to interested cooperating laboratories; digest of available information on moist storage and water storage temperature controlled apparatus; study of question of calibration of compression testing machines used for plastic mortar tests; study of variables involved in cube mold specifications; improvement of tension test machine grips.

It is planned to submit to the committee at the June meeting a report transmitting the findings and suggestions of the subcommittee relating to the above mentioned subjects for study.

Respectfully submitted on behalf of the subcommittee,

G. E. WARREN,
Chairman.

REPORT OF COMMITTEE C-3
ON
BRICK

Committee C-3 on Brick has held two meetings during the past year, in Atlantic City, N. J., on June 27, 1934, and in Philadelphia, Pa., on March 7, 1935.

Several of the subcommittees have been very active during the year. Revisions of the specifications and methods of testing brick for which the committee is responsible have been made and other revisions are under consideration. At the meeting in Philadelphia on March 7, 1935, a report was submitted by Subcommittee XI on Weathering and Porosity (D. E. Parsons, chairman). In connection with the work of the subcommittee there were also submitted at this meeting papers by D. E. Parsons on "Comparison of Natural Weathering with Laboratory Tests of Clay Brick," and by J. W. McBurney on "The Relation of Freezing and Thawing Resistance to Physical Properties of Clay and Shale Building Brick." Committee C-3 accepted the report and the two papers for inclusion in the annual report and they are accordingly appended hereto. These papers introduce a method for determining the weather resistance and durability of clay building brick.

It has been generally recognized that the present Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30) have afforded the consumer very little protection regarding factors of weathering, and a revision of the specifications has accordingly been prepared by Subcommittee VIII on Clay Building Brick (J. A. Pugh, chairman) and is being submitted for publication as tentative, as appended hereto.[1]

Realizing that the present Standard Methods of Testing Brick (Compression, Flexure, Absorption) (C 67 – 31) do not have the sequence of tests usually followed in testing brick, and lacking in several other details, a revision of these testing procedures has been prepared by Subcommittee V on Methods of Testing (F. B. Lysle, chairman) and is proposed for publication as tentative, as appended hereto.[2]

RECOMMENDATIONS AFFECTING STANDARDS

The committee recommends for publication as tentative in the forms as appended hereto[1,2] extensive revisions in the following two standards under its jurisdiction:

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[1] See p. 788.—ED.
[2] See p. 791.—ED.

Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30)[1]

Methods of Testing Brick (Compression, Flexure, Absorption) (C 67 – 31)[1]

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 37 members; 27 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballot Marked "Not Voting"
PROPOSED TENTATIVE REVISION OF STANDARDS			
Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30)	27	0	0
Standard Methods of Testing Brick (Compression, Flexure, Absorption) (C 67 – 31)	26	0	1

This report has been submitted to letter ballot of the committee which consists of 37 members; 27 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. T. SHELLEY,
Chairman.

J. W. WHITTEMORE,
Secretary.

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[1] 1933 Book of A.S.T.M. Standards, Part II, pp. 109 and 128.

REPORT OF SUBCOMMITTEE XI ON WEATHERING AND POROSITY

The Society's specifications for building brick (made from clay or shale) which were effective between the years 1919 to 1927, contained requirements on the water absorption of brick.[1] These requirements were omitted when the specifications were revised in 1927. The revised specifications[2] afford no effective protection to the purchaser against the acceptance of brick of inferior durability. In the words of Committee C-3(**1**),[3] "It was recognized that the specifications . . . are incomplete due to absence of any test for or classification based on resistance to weathering . . ." There is need for a simple, rapid, and accurate test, the results of which would serve to classify brick according to their probable durabilities. Much new information on the properties of brick has been developed since 1927 and the data now available seem to afford a basis for specification requirements relating to durability. In this report Subcommittee XI gives a brief review of simple methods for classifying brick with respect to durability, and suggests a basis for specification requirements.

AGENTS OF WEATHERING

Most investigators of the weathering of clay brick agree that, of the several agents of weathering, frost action and the crystallization of salts within the voids are chiefly responsible for the disintegration of clay brick. The investigations of Jones(**2**), Schlick and Staley(**3**), Orton(**4**), Kreuger(**5**), Laurie(**6**), McIntyre(**7**), Bole(**8**), the British Building Research Board(**9**) and others confirm this. Moreover, the observations of these investigators as well as those of Howat(**10**), Furlong(**11**) and others indicate that the resistance of a given product depends largely on the heat treatment during manufacture. Manufacturers of brick as well as discriminating users seem to agree that if a brick is "well burned" it is likely to be of satisfactory durability. All of these subjects have been discussed by several writers. Many of their discussions and data are summarized more fully in the review and abstracts of the literature given in the Symposium on Weathering Characteristics of Masonry Materials(**12,13**).

METHODS OF ESTIMATING DURABILITY

Jones(**2**) discussed the effects of sizes of pores and of the proportion of pores filled with water when freezing occurred upon the destructive action of the expansion of ice. Hirschwald(14) suggested the ratio of the volume of pores filled by simple immersion to total volume of accessible pores (his "saturation coefficient") as one convenient measure of the probable resistance to frost action. Kreuger(6), McBurney and Lovewell(12,15) have shown that quantities similar to Hirschwald's saturation coefficient are significantly related to the destructive effects of frost action. The data of McBurney and Lovewell(15) afford a means for estimating the relative values of different criteria which may be used to predict the resistance of brick to frost action. Moreover, these authors suggested several criteria for selecting brick that resisted 51 cycles of their weathering test. They showed that the ratio 48-hr. cold-water absorption to 5-hr. boiling-water absorption gave a better indication of frost resistance than any other single measure, but that a criterion involving a combination of this ratio with a limit on absorption or strength gave a sharper division between brick which resisted and those which were disintegrated by the tests. In Appendix I to this report, J. W. McBurney presents comparisons between some of the physical properties of brick and their resistance to freezing and thawing, while the data given by D. E. Parsons in Appendix II afford some comparisons between natural weathering and the results of laboratory tests.

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[1] See the Standard Specifications for Building Brick (C 21 – 20), 1924 Book of A.S.T.M. Standards, p. 665.

[2] See the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 30), 1933 Book of A.S.T.M. Standards, Part II, p. 109.

[3] The boldface numbers in parentheses refer to the reports and papers given in the list of references appearing on p. 245.

The results of these investigations indicate that brick are apt to be highly resistant to severe frost action if the ratio of absorption by 48-hr. cold-water immersion to that by 5-hr. boiling water (C_{48}/B_5 ratio) is less than 0.80, the compressive strength exceeds 2500 lb. per sq. in. and the absorption by 5-hr. boiling is less than 20 per cent. It appears that the foregoing requirement would be adequate even if the bricks were for use where exposed to very severe frost action as in retaining walls, sidewalks and hydraulic structures. For more ordinary use, as in the walls of buildings in cold climates, a less rigid requirement may suffice. The subcommittee suggests that for these exposures the maximum C_{48}/B_5 ratio be limited to 0.85, and the minimum compressive strength to 2500 lb. per sq. in.

The C_{48}/B_5 ratio is a measure of the degree of saturation obtained during the submergence in water. It affords, therefore, a measure of the proportion of the pore space, accessible to water, that is filled by simple soaking for a standard time, the remainder being available to relieve the pressure which tends to develop as the entrained water freezes. Comparisons by McBurney(16) of water absorptions by 24 hr. and 48 hr. simple soaking indicate that the C_{24}/B_5 ratio (24-hr. cold-water absorption to the absorption by 5-hr. boiling water) could be substituted for the C_{48}/B_5 ratio without changing materially the values for bricks having ratios greater than 0.80. Obviously, this would decrease by one day the time required for a test.

The C/B ratio has not been shown to be an effective measure of the resistance of brick to the crystallization of salts. However, the values of this ratio tend to decrease with an increase in the heat treatment, and several investigators including Palmer(17) and Hirsch(18) have noted the same tendency with respect to the soluble salt content of brick. Presumably, the increase in strength resulting from higher firing temperatures improves the resistance to stresses caused by crystallization. And the British Building Research Board(9) has found a similar ratio to give a measure of "microporosity" of Portland stone and also an indication of resistance of this material to salt crystallization. These considerations together with comparison between crystallization tests and freezing tests(4,9) indicate that the C/B ratio may be significantly related to resistance of brick to both agents of weathering.

REFERENCES

(1) Report of Committee C-3 on Brick, *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 308 (1928).

(2) J. O. Jones, "The Relation of Hardness of Brick to Their Resistance to Frost," *Transactions*, Am. Ceramic Soc., Vol. 9, p. 528 (1907).

(3) W. J. Schlick and H. F. Staley, "An Investigation of Tests of Iowa Shale Drain Tile," *Bulletin No. 49*, Iowa State College Engineering Experiment Station, Ames, Iowa (1918).

(4) Edward Orton, Jr., "A Study of the Proposed A.S.T.M. Tentative Specifications for Building Brick and a Correlation of Their Requirements with Sodium-Sulfate Treatment and Actual Treating," *Proceedings*, Am. Soc. Testing Mats., Vol. 19, Part I, p. 268 (1919).

(5) H. Kreuger, "Investigations of Climatic Action on the Exteriors of Buildings," *Transactions*, Royal Swedish Inst. Scientific Industrial Research, No. 24 (1923).

(6) A. P. Laurie, "The Decay of Modern Brickwork," *British Clayworker*, Vol. 35, p. 280 (1927).

(7) W. A. McIntyre, "Factors Governing the Durability of Clay Building Materials," *Transactions*, Ceramic Soc. (British), Vol. 28, March, 1929, p. 101.

(8) G. A. Bole, "The Drain Tile Industry of Ohio," *The Clayworker*, Vol. 90, p. 286 (1928).

(9) Report of the Building Research Board for the Year 1933, Department of Scientific and Industrial Research, London (1934).

(10) W. L. Howat, "The Effect of Saturated Sodium Sulfate Solution upon Structure of Clay Burned to Different Temperatures," *Transactions*, Am. Ceramic Soc., Vol. 17, p. 249 (1915).

(11) I. Furlong, "Alkali Attack on Concrete Roads and Building Brick. A Study of Disintegration in Glenn County, California," *Engineering News-Record*, Vol. 89, July 13, 1922, p. 64.

(12) J. W. McBurney, "The Weathering of Structural Clay Products: A Review," *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part II, p. 745 (1931).

(13) D. E. Parsons, "Bibliography on the Weathering of Structural Clay Products," *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part II, p. 825 (1931).

(14) J. Hirschwald, "Handbuch der Bautechnischen Gesteinprüfung," Gebrüder Borntraeger, Berlin (1912).

(15) J. W. McBurney and C. E. Lovewell, "Strength, Water Absorption and Weather Resistance of Building Bricks Produced in the United States," *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 636 (1933).

(16) J. W. McBurney, "Water Absorption and Penetrability of Brick," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 711 (1929).

(17) L. A. Palmer, "Cause and Prevention of Kiln and Dryhouse Scum and of Efflorescence on Face Brick Walls," National Bureau of Standards *Technologic Paper No. 370* (1928).

(18) H. Hirsch, "The Origin and Prevention of Efflorescing Salts in Brick Manufacture," *Tonindustrie-Zeitung*, Vol. 51, p. 1044 (1927).

(19) J. W. Whittemore and P. S. Dear, "Physical Properties of Common and Face Brick Manufactured in Virginia," *Bulletin No. 6*, Virginia Polytechnic Inst., March, 1930.

Respectfully submitted on behalf of the subcommittee,

D. E. PARSONS,
Chairman.

APPENDIX I

THE RELATION OF FREEZING-AND-THAWING RESISTANCE TO PHYSICAL PROPERTIES OF CLAY AND SHALE BUILDING BRICK[1]

By J. W. McBurney[2]

In a previously published paper[3] the following statement was made, which was based upon limited data: ". . . it is evident that strength and water absorption provide no measure whatsoever for judging the relative resistance to freezing and thawing of these two salmon grades. The only clue to their behavior is provided by their ratios of 48-hr. cold-water absorption to 5-hr. boiling-water absorption." In another paper[4] data were presented resulting from 51 cycles of freezing and thawing on approximately 480 brick specimens and the following conclusions were stated: "The combination, not less than 2500 lb. per sq. in. compressive strength with an absorption ratio of not more than 0.80, or a compressive strength of not less than 6000 lb. per sq. in. with an absorption ratio of not more than 0.85, insures the withstanding of 51 cycles of freezing and thawing.

"Likewise the combination, not more than 18 per cent water absorption by 5 hr. boiling water with an absorption ratio of not more than 0.80, or a water absorption of not more than 12 per cent by 5 hr. boiling with an absorption ratio not exceeding 0.85, insures the withstanding of 51 cycles of freezing and thawing."

The ratio 48-hr. cold-water absorption to 5-hr. boiling-water absorption is represented hereafter in this paper by the symbol C_{48}/B_5.

The present paper further analyzes the data obtained at the National Bureau of Standards in the survey of the properties of clay and shale building brick and provides a comparison of test results at 12 cycles, 24 cycles, 51 cycles and 75 cycles of freezing and thawing.

SELECTION OF TEST SPECIMENS

Reference is made to the 1933 paper[5] for an account of the survey which provided the samples from which the specimens here considered were selected. It should be emphasized that the specimens for the freezing-and-thawing tests were not selected at random from the 3886 bricks received and did not represent a cross-section or fair sample of the survey. With but few exceptions all of the specimens for the freezing-and-thawing tests were selected because they were of doubtful weather resistance. The number of bricks subjected to these tests were as follows: 378 bricks were frozen and thawed 75 times, 480 at least 51 times, 625 at least 24 times and 680 at least 12 times.

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[1] Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Washington Representative of the American Standards Association at the National Bureau of Standards, Washington, D. C.

[3] J. W. McBurney, "The Weathering of Structural Clay Products: A Review," *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part II, p. 745 (1931).

[4] J. W. McBurney and C. E. Lovewell, "Strength, Water Absorption and Weather Resistance of Building Brick Produced in the United States," *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 636 (1933).

[5] *Loc. cit.*

Dried half bricks were totally immersed in water for 48 hr., then frozen 20 hr. partially immersed in water. They were then thawed in water at room temperature for 4 hr. After each third freezing they were oven dried at 100 C. and weighed. Then the same procedure of soaking, freezing and thawing was repeated. A more detailed description of this method of test is given on page 750 of the 1931 paper.[1]

PRESENTATION OF DATA

Figure 1 was constructed in the following manner: For each specimen tested a card had been prepared giving the results of strength and water-absorption measurements as well as the number of freezing-and-thawing cycles survived. If no failure resulted from freezing and thawing, the number of cycles used was stated. These cards were first sorted with respect to number of cycles. For example, all cards reporting successful resistance to 75 or more cycles were placed in one group and all cards reporting failure on or before 75 cycles in another. All cards in each group showing C_{48}/B_5 ratios of less than 0.40 were removed and counted. Of the sample records so selected, all were in the group which had successfully withstood 75 or more cycles of freezing and thawing. In Fig. 1 this was indicated as 100 per cent of specimens found satisfactory of those with C_{48}/B_5 ratio less than 0.40. Corresponding percentages were calculated after adding the specimen records for samples with C_{48}/B_5 ratios from 0.40 to 0.50 and thereafter by 0.10 increases up to a ratio of 1.00. Similar sortings and calculations were made for 12, 24, and 51 cycles of freezings and thawings. This completed Fig. 1.

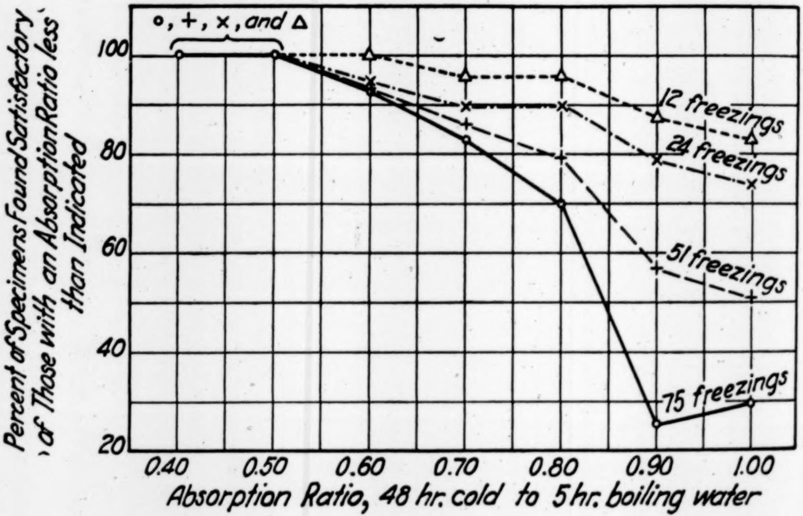

FIG. 1.—Effect of Absorption Ratio on Resistance to Freezing and Thawing of Bricks. All bricks considered.

Figure 2 was constructed by first removing all sample records showing bricks with flat compressive strength of less than 2500 lb. per sq. in., then sorting and making calculations as for Fig. 1. Figure 3 correspondingly was prepared from data with all sample records showing 5-hr. boiling-water absorptions more than 20 per cent eliminated. Figure 4 combines the eliminations of Figs. 2 and 3.

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[1] *Loc. cit.*

DISCUSSION

If a sufficiently high requirement for flat compressive strength is set, satisfactory resistance to the disintegrating effect of 75 cycles of freezing and thawing can be assured with a degree of probability approaching certainty. Likewise, a sufficiently low limit for water absorption measured by the 5-hr. boiling-water test will give equal assurance. From data available the requirements of a compressive strength not less than 12,000 lb. per sq. in. or a water-absorption by 5 hr. boiling of not more than 12 per cent

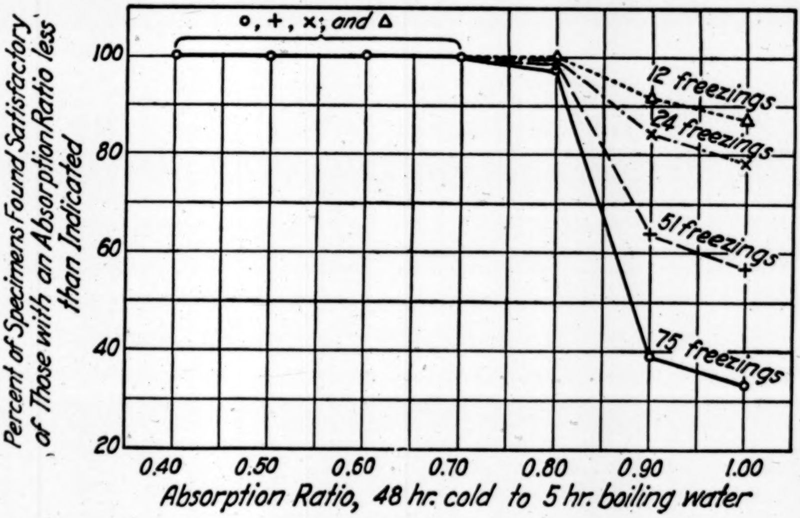

FIG. 2.—Effect of Absorption Ratio on Resistance to Freezing and Thawing of Bricks Whose Strength Is Not Less Than 2500 lb. per sq. in.

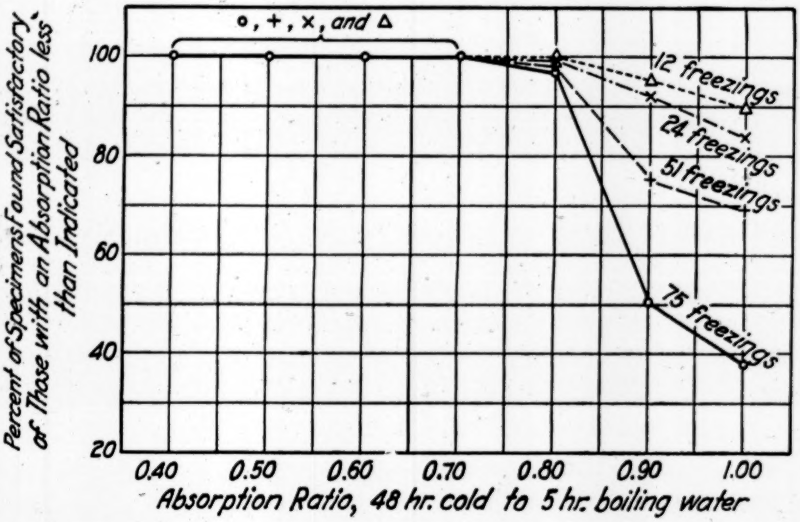

FIG. 3.—Effect of Absorption Ratio on Resistance to Freezing and Thawing of Bricks Whose 5-hr. Boiling-Water Absorption Is Not More Than 20 per cent.

provide practical elimination of the possibility of failure to withstand 75 cycles of freezing and thawing. These two limits, individually or in combination, are entirely impractical for specification purposes since they eliminate more than half of the building bricks produced in the United States. Reference is made to Table III of the 1933 paper.[1]

From Fig. 1 it appears that the value for the C_{48}/B_5 ratio must not exceed 0.50 if certain elimination of unsatisfactory brick is desired. This, again, is impractical on account of excessive elimination of brick known to be satisfactory in service. Figures 2 and 3 illustrate the improvement resulting from combining water absorption or strength with the C_{48}/B_5 ratio as a measure of freezing and thawing action. Reference is made to Tables VII and VIII of the 1933 paper,[1] for a tabular presentation of the data for 51 cycles used in Figs. 2 and 3.

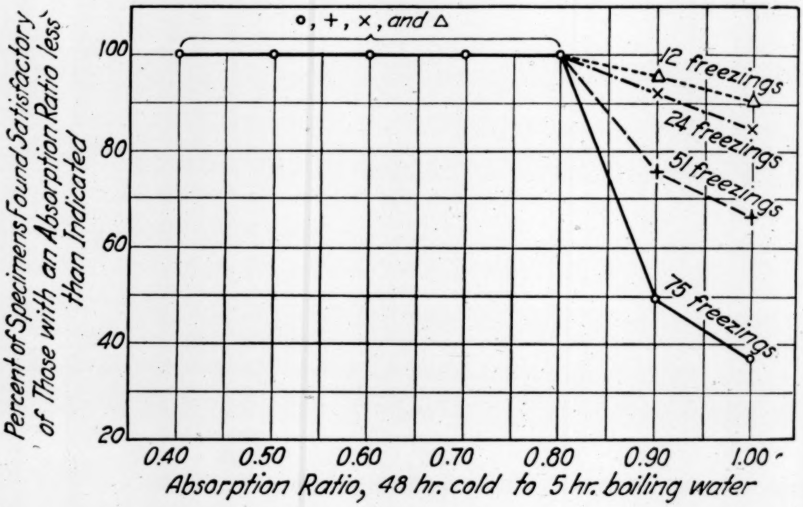

FIG. 4.—Effect of Absorption Ratio on Resistance to Freezing and Thawing of Bricks Whose Strength Is Not Less Than 2500 lb. per sq. in. and Whose 5-hr. Boiling-Water Absorption Is Not More Than 20 per cent.

The ultimate goal of a classification which will accept all satisfactory bricks and reject all unsatisfactory ones is most nearly approached by the method illustrated in Fig. 4. The combination of a flat compressive strength not less than 2500 lb. per sq. in. and a water absorption by 5-hr. boiling of not more than 20 per cent together with a C_{48}/B_5 ratio of not more than 0.80 effectively eliminates all samples failing from 75 cycles of freezing and thawing.

Obviously, a series of relations could be set up between strength-absorption limits and ratios, the extreme combinations being 12,000 lb. per sq. in. strength, 12 per cent water absorption and a C_{48}/B_5 ratio of 1.00 for one limit as against no minimum strength requirement, no maximum absorption limit and a ratio of 0.50 for the other limit. The combination given in the preceding paragraph rejects the fewest specimens not rejected by 75 cycles of freezing and thawing.

If an intermediate degree of resistance is sought, raising the limit of the C_{48}/B_5 ratio to 0.85 would accomplish the purpose. If Figs. 1 to 4 had been plotted to 0.05

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[1] *Loc. cit.*

ratio differences instead of 0.10 as was done, the interpolated points would in general have fallen on or near the lines connecting the points shown.

Twenty-four hours would be saved in testing if there be substituted for the ratio 48-hr. cold-water absorption to 5-hr. boiling-water absorption, the ratio 24-hr. cold-water absorption to 5-hr. boiling-water absorption. The data obtained by the author in 1929[1] show that the two ratios usually do not differ by more than 0.03 when the latter exceeds 0.80.

Comparison of numbers of samples failing with number of freezing-and-thawing cycles used indicates that the number of failures is proportional to the number of cycles. This may be of little significance beyond indicating that the distribution of resistant and non-resistant specimens in the samples was of such a nature as to produce this result.

Conclusions

From the data here considered the following conclusions seem justified:

1. Neither strength, water absorption nor ratio of 48-hr. cold-water absorption to 5-hr. boiling-water absorption (C_{48}/B_5), considered separately, provide a practical means of predicting the resistance of clay or shale building brick to cycles of freezing and thawing.

2. Strength *or* water absorption in combination with the ratio 48-hr. cold-water absorption to 5-hr. boiling-water absorption (C_{48}/B_5) provides a very much better separation of brick into resistant and nonresistant with respect to freezing-and-thawing cycles.

3. Three measures together, strength, water absorption and water-absorption ratio provide the most accurate prediction of freezing-and-thawing resistance found to date.

4. To insure the withstanding of 75 cycles of freezing and thawing the requirements of a flat compressive strength of not less than 2500 lb. per sq. in., a water absorption by 5-hr. boiling of not more than 20 per cent, and a ratio 48-hr. cold-water absorption to 5-hr. boiling-water absorption (C_{48}/B_5) of not more than 0.80 are recommended.

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[1] J. W. McBurney, "The Water Absorption and Penetrability of Brick," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 714 (1929).

APPENDIX II

COMPARISON OF NATURAL WEATHERING WITH LABORATORY TESTS OF CLAY BRICK[1]

BY D. E. PARSONS[2]

Direct comparisons of the effects of the weathering of brick with the results of laboratory freezing-and-thawing tests are made so seldom that the following comparisons may be useful.

Bricks showing signs of weathering were taken from the walls (above grade) of six buildings located in New England. Two bricks which at that time had been exposed for periods ranging from 6 to 17 yr., were obtained from each building.

As all of the bricks had been stretchers in the exposed faces of the walls, one face of each brick had been weathered while the opposite face had the appearance of a new brick. The exposed faces of some of the bricks were only slightly eroded; of others, deeply pitted and of the rest, spalled.

Each brick was broken transversely to obtain a value for modulus of rupture; one of the halves was then subjected to freezing and thawing and the other was reserved. Surfaces of the specimens under test which had not been exposed to natural weathering were compared with the weathered surface of the reserved half brick. This provided a means for judging whether the laboratory freezing and thawing produced, on the same brick, a weathered appearance similar to that caused by the natural agents of weathering and, if so, how many freezings and thawings were required to produce the same appearance as the actual exposure.

In addition to the 12 bricks taken from the walls of buildings, 14 other bricks, either 2 or 3 each from six different sources, were subjected to the same laboratory tests.

TEST PROCEDURE

Each brick was dried and tested for modulus of rupture. The rough edges and surfaces of one of the half-bricks were then ground to remove the weathered material and other portions which might readily become loosened during handling. In turn, it was then weighed, submerged in water at room temperature for 48 hr., frozen in air at a temperature of about 20 F. (-7 C.) for about 17 hr. and thawed by submerging in water at room temperature for about 7 hr. The alternating exposures to freezing in air and thawing in water were continued for 10 cycles, when the specimens were dried for 20 to 24 hr. in a ventilated oven at 230 F. (110 C.) and weighed. This procedure of soaking for 48 hr. followed by 10 cycles of freezing and thawing and then a redrying was repeated until either the specimen was disintegrated or had withstood 180 cycles of freezing and thawing and 18 cycles of wetting and drying. The laboratory weathering test was, therefore, a combination of exposures to changes in temperature, wetting and drying and frost action. Effects of the weathering tests were determined by two methods:

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[1] Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Chief, Masonry Construction Section, National Bureau of Standards, Washington, D. C.

TABLE I.—COMPARISON OF LABORATORY WEATHERING WITH NATURAL WEATHERING.

Brick	Duration of Exposure in Wall, yr.	Number of Laboratory Freezings Equivalent to Weathering	Number of Laboratory Freezings per Year Exposure
No. 1	17	60	3.5
No. 2	17	40	2.4
No. 3	15	30	2.0
No. 4	15	30	2.0
No. 5	12	40	3.3
No. 6	12	30	2.5
No. 7	6	20	3.3
No. 8	6	15	2.5
No. 9	13	60	4.6
No. 10	13	40	3.1
No. 11	7	20	2.9
No. 12	7	20	2.9
Average	..	..	2.9

TABLE II.—RESULTS OF PHYSICAL TESTS AND OF LABORATORY WEATHERING TESTS.

Brick	Modulus of Rupture, lb. per sq. in.	Compressive Strength (flatwise), lb. per sq. in.	Bulk Specific Gravity[a]	Specific Gravity[b]	Porosity, per cent	Absorption in Terms of Dry Weight, per cent			Coefficient of Water Saturation[c]	C_{48}/B_5 Ratio[d]	Loss in Weight After 100 Freezings, per cent[e]	Loss in Weight After 180 Freezings, per cent[e]
						By Cold Immersion		By Boiling 5 hr. B_5				
						15 min.	48 hr. C_{48}					
BRICKS TAKEN FROM WALLS OF BUILDINGS												
No. 1	950	4410	1.98	2.72	27.2	4.3	7.1	12.1	0.52	0.59	0.5	0.7
No. 2	850	3790	1.88	2.73	31.1	9.8	10.9	16.2	0.66	0.67	0.5	0.9
No. 3	390	3150	1.54	2.72	43.4	20.1	21.5	22.8	0.76	0.94	2.8	7.6
No. 4	470	2640	1.65	2.73	39.5	13.0	18.1	19.0	0.76	0.95	5.1	failed
No. 5	640	3930	1.56	2.69	42.0	19.0	20.9	24.1	0.78	0.87	failed	failed
No. 6	610	4380	1.58	2.70	41.5	19.2	20.7	23.2	0.79	0.89	6.4	6.8
No. 7	510	2470	1.55	2.73	43.2	20.8	21.9	23.5	0.79	0.93	0.8	1.5
No. 8	420	3010	1.60	2.73	41.4	19.0	20.4	21.8	0.79	0.94	2.1	2.8
No. 9	650	1980	1.84	2.72	32.3	12.0	13.0	18.2	0.74	0.71	0.5	1.2
No. 10	...	2970	1.74	2.74	36.4	15.4	16.2	19.0	0.78	0.85	1.0	1.5
No. 11	850	3640	1.70	2.75	38.2	15.6	17.3	19.2	0.77	0.90	1.0	1.6
No. 12	660	3160	1.64	2.75	40.3	18.0	20.0	21.1	0.81	0.95	1.4	2.2
NEW BRICKS												
No. 13	1780	5690	2.01	2.71	25.8	5.3	7.5	12.0	0.58	0.63	0.2	0.4
No. 14	1470	11580	2.00	2.69	25.6	5.3	7.4	10.6	0.58	0.70	0.0	0.1
No. 15	1620	14000	2.22	2.67	16.8	0.8	3.0	5.4	0.40	0.56	0.2	0.3
No. 16	1350	14840	2.20	2.66	17.2	0.7	3.2	6.3	0.41	0.51	0.0	0.0
No. 17	1570	8930	1.89	2.68	29.5	8.7	9.8	13.0	0.63	0.75	0.3	0.4
No. 18	1220	9510	1.85	2.70	31.4	10.6	11.8	14.0	0.70	0.84	0.1	0.2
No. 19	940	3510	1.64	2.75	40.3	16.8	19.7	23.0	0.80	0.86	0.5	0.8
No. 20	510	4470	1.63	2.76	40.9	17.7	19.7	21.7	0.79	0.91	0.8	0.9
No. 21	620	2580	1.59	2.77	42.6	19.7	22.3	25.0	0.83	0.89	1.7	2.3
No. 22	870	3310	1.90	2.79	31.9	4.1	9.6	14.9	0.57	0.64	0.5	0.6
No. 23	680	3010	1.91	2.79	31.5	6.0	10.8	16.2	0.66	0.67	0.7	1.2
No. 24	720	3970	1.74	2.80	37.8	13.0	18.6	22.7	0.86	0.82	0.8	1.5
No. 25	1690	2750	1.70	2.81	39.5	7.0	11.1	16.2	0.48	0.69	0.3	0.6
No. 26	1220	2550	1.70	2.82	39.7	11.4	16.0	20.7	0.69	0.77	0.7	1.2

[a] For 20/20 C.

[b] For 20/20 C. Determinations made on powdered material passing No. 100 sieve.

[c] Ratio of volume of water absorbed during 48-hr. submergence in water at room temperature to total pore space.

[d] Ratio of water absorption by 48-hr. submergence in water at room temperature to that absorbed by 5-hr. boiling.

[e] All weight obtained with dry specimens.

(*1*) loss of weight after each 10 cycles of freezing and thawing and 1 cycle of drying, and

(*2*) visual inspection and rating according to the arbitrary scale noted in Table III.

The visual comparisons of the unweathered faces of the halves undergoing freezing-and-thawing tests with the weathered faces of the reserved halves were made after each successive 10 cycles of freezing and thawing. The specimens always were dry when the comparisons were made.

TABLE III.—VISUAL RATINGS OF SPECIMENS.

NOTE.—A = No apparent effect.
B = Slightly worn or eroded appearance.
C = Surface pitted or spalled (shallow).
D = Disintegration, cracks or spalls causing structural weakness.
E = Useless as a structural unit.

Brick	Visual Ratings of Specimens		
	Previously Unexposed Face After Freezing and thawing		Exposed Face (as received)
	100 cycles	180 cycles	
No. 1	B	B	B
No. 2	B	B	B
No. 3	E	E	D
No. 4	E	E	D
No. 5	E	E	B
No. 6	D	E	C
No. 7	C	C	B
No. 8	C	C	B
No. 9	B	B	B
No. 10	B	C	B
No. 11	C	C	B
No. 12	C	C	B
No. 13	A	A	..
No. 14	A	A	..
No. 15	A	A	..
No. 16	A	A	..
No. 17	A	B	..
No. 18	A	B	..
No. 19	B	B	..
No. 20	B	B	..
No. 21	C	C	..
No. 22	B	B	..
No. 23	B	B	..
No. 24	B	B	..
No. 25	A	B	..
No. 26	B	B	..

The other halves of the bricks (not subjected to the weathering test) were tested for absorption, bulk specific gravity, compressive strength and specific gravity. The results of these tests are given in Table II.

RESULTS AND DISCUSSION

Comparison of Effects of Weathering with Laboratory Weathering Test:

With one exception (brick No. 5), it was found that the exposures to the laboratory weathering test caused the unweathered surface (not exposed to natural weathering) of each of the halves undergoing the tests to exhibit an appearance which was similar to that of the weathered face of the reserved half. The approximate number of cycles of the laboratory tests required to cause these two surfaces to appear alike are given in Table I. Brick No. 5 cracked during the first 10 cycles of freezing and thawing, the cracks radiating from and evidently caused by a pebble inclusion. For the comparisons shown in Table I, these cracks were disregarded and the data were based upon visual comparisons of surfaces.

The data of Table I indicate a rough relation between the effects of weathering and of the laboratory weathering test. They show that, for the conditions of tests, about 3 of the laboratory cycles of freezing and thawing caused, on the average, an effect which appeared to be similar to that of one year of the natural weathering.

Relations Between Physical Properties of Bricks and Results of Laboratory Weathering Tests:

The data of Tables II and III show that no one of the properties, compressive strength, modulus of rupture, specific gravity, porosity or absorption by immersion in cold water or in boiling water were accurate measures of the performance of the bricks in the weathering tests. The coefficient of water saturation[1] was a somewhat better measure, but the values of the C_{48}/B_5 ratio[1] were more closely related to the results of the weathering tests than any other single property compared.[2]

The results may be expressed in different ways. For example, of the 26 bricks, 12 had a C_{48}/B_5 ratio less than 0.8, none of which lost more than 1.2 per cent during 180 freezings and thawings. Moreover, all but three of the 14 bricks having a C_{48}/B_5 ratio greater than 0.8 lost more than 1.4 per cent; the three exceptions had compressive strengths greater than 3500 lb. per sq. in.

The three bricks which showed marked effects of weathering when taken from the walls had C_{48}/B_5 ratios of 0.89 or more.

COMMENTS

Data are not available to indicate to what extent (if any) the exposure to natural weathering affected the strength, the absorption and the behavior in the laboratory weathering tests. It is, perhaps, superfluous to remark that some of the specimens were selected because of their poor durability and that those specimens were not representative of commercial bricks.

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[1] Defined in Table II.

[2] This is in agreement with the findings of J. W. McBurney, C. E. Lovewell, "Strength, Water Absorption and Weather Resistance of Building Bricks Produced in the United States," *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 636 (1933). See also: J. W. McBurney, "The Weathering of Structural Clay Products: A Review," and D. E. Parsons, "Bibliography on the Weathering of Structural Clay Products," in the Symposium on Weathering Characteristics of Masonry Materials, *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part II, pp. 745 and 825, respectively (1931).

REPORT OF COMMITTEE C-4

ON

CLAY PIPE

Committee C-4 on Clay Pipe held one meeting during the past year, on March 5, 1935, at Philadelphia, Pa., at the time of the Spring group meetings of A.S.T.M. committees.

Since this is the first formal report to the Society presented by Committee C-4 since 1932, the committee wishes to record that the Standard Specifications for Clay Sewer Pipe (C 13 – 24) were withdrawn at the 1933 annual meeting.[1] Also, the committee presented to the Society in 1933 through Committee E-10 on Standards certain revisions of the Tentative Specifications for Clay Sewer Pipe (C 13 – 32 T) which were accepted for publication by Committee E-10 at a meeting held on August 16, 1933.[2] The specifications were published in their revised form in the 1933 *Proceedings*.[3]

At the March meeting the committee reviewed in detail the existing Tentative Specifications for Clay Sewer Pipe (C 13 – 33 T),[3] in preparation for proposing to the Society their adoption as standard. As the result of this study the committee proposes the following minor revisions in these specifications and recommends that the specifications as revised be submitted to the Society for adoption as standard:

Section 5.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

5. When [tested] *testing* with either hydrochloric, nitric, sulfuric, or acetic acid, *as specified by the purchaser*, the acid having a normality of one (1.0 N), the percentage of acid-soluble matter shall not exceed 0.25 per cent, calculated as sulfates. The purpose of this test is to determine the resistance of pipe to the action of acids and its use is optional.

Section 11 (*a*).—Change to read as follows by the omission of the word in brackets:

11. (*a*) The specimens shall first be freed from all visible moisture. When dry, each specimen shall be [weighed,] measured and inspected. The results of these observations shall be recorded.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 15 (1933).

[2] In submitting these revised tentative specifications to Committee E-10 on Standards, Committee C-4 reported results of the letter ballot vote as follows: Of a total membership of 17, 14 ballots were returned, of which 11 to 14 were affirmative, 0 to 2 negative, and 0 to 2 marked "not voting." The range in votes was due to the recording of votes separately on each of the revisions recommended.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 691; also 1934 Book of Tentative Standards, p. 403.

Section 14.—Change the fifth sentence to read as follows by the addition of the italicized words:

> Before the pipe is placed, a fillet of plaster of Paris *or other equalizing material, such as sand and sulfur,* thick enough to compensate for the inequalities of the pipe barrel shall be cast on and between the two lower bearings.

Section 20 (b).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> (*b*) However, in case of failure of pipe to meet the requirements under the specified method, [especially where] *and* the accuracy of the testing machine is questioned, a retest at the request of the manufacturer shall be made upon a machine whose accuracy is known or [that] the machine originally used *shall* be recalibrated before the retest is made.

Section 22.—Change the last sentence of this section from its present form: namely,

> Pipes intended to be straight shall not have variation in alignment of more than ⅛ in. per foot of length, this measurement to mean the maximum ordinate as measured from the concave side of the pipe.

to read as follows:

> Pipes intended to be straight shall have a maximum ordinate as measured from the concave side of the pipe of not to exceed ⅛ in. per foot of length.

Table II.—Change the last column of the table under the heading "Thickness of Socket (T_s)" to read as follows by the addition of the italicized dimension and the omission of the dimension in brackets:

> The thickness of the socket [¼ in.] *⅛ in.* from its outer end shall be not less than three-fourths of the thickness of the barrel of the pipe.

There exists a typographical error in the third column of Table II; for size 18 in. the diameter should be 22¼ in. instead of 22½ in.; for size 21 in. the diameter should be 25⅞ in. instead of 25¾ in. It is recommended that these corrections be made.

The committee has also given much study to the Standard Definitions of Terms Relating to Sewer Pipe (C 8 – 24)[1] and has prepared a complete revision of the numerous terms referring to clay sewer pipe and pipe materials. These revisions have been incorporated in the proposed Tentative Definitions of Terms Relating to Clay Sewer Pipe appended hereto,[2] which the committee recommends for publication as a tentative revision of the Standard Definitions C 8.

The above recommendations have been submitted to letter ballot of the committee, which consists of 17 members; 16 members returned their ballots, the results being as follows:

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 218.

[2] See p. 829.—ED.

Items	Affirm-ative	Neg-ative	Ballots Marked "Not Voting"
I. ADOPTION OF TENTATIVE STANDARD AS STANDARD Tentative Specifications for Clay Sewer Pipe (C 13 - 33 T), as revised	13	1	2
II. PROPOSED REVISION OF STANDARD Standard Definitions of Terms Relating to Sewer Pipe (C 8 - 24)	14	0	2

This report has been submitted to letter ballot of the committee which consists of 17 members; 17 members returned their ballots, of whom 16 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

G. T. HAMMOND,
Chairman.

G. C. D. LENTH,
Secretary.

REPORT OF COMMITTEE C-8
ON
REFRACTORIES

Committee C-8 on Refractories held two meetings during the year; in Pittsburgh, Pa., on September 19, 1934, and in Buffalo, N. Y., on February 19, 1935, the latter in conjunction with the annual meeting of the American Ceramic Society.

At the Buffalo meeting, copies of the volume of A.S.T.M. Standards on Refractory Materials issued by the Society in February, 1935, were made available to the members of the committee.

Committee C-8 has continued its very active work during the year and it is gratifying to observe the widespread use that is now being made of the A.S.T.M. tests and specifications pertaining to refractories.

Subsequent to the 1934 annual meeting, the committee presented through Committee E-10 on Standards the following recommendations affecting its standards. The new tentative standards and revisions were accepted for publication as tentative[1] by Committee E-10 on December 27, 1934, and appear in the volume of A.S.T.M. Standards on Refractory Materials.

Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 – 34 T).—So numerous were the revisions that were necessary to bring the Standard Specifications for Malleable Furnace Brick (C 63 – 28) up to date that it was deemed advisable by the committee to withdraw the standard and submit new tentative specifications for publication.

Tentative Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 – 34 T).—It was also desired to bring up to date the Standard Specifications for Boiler Furnace Brick (C 64 – 28) and the committee accordingly recommended that the standard specifications be withdrawn and replaced by new tentative specifications.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee C-8 reported the following results of the letter ballot vote of a total of 33 ballots returned from a committee membership of 34: Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 – 34 T), 25 affirmative, none negative and 8 ballots marked "not voting"; withdrawal of Standard Specifications C 63 – 28, 29 affirmative, none negative and 4 ballots marked "not voting"; Tentative Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 – 34 T), 26 affirmative, 1 negative and 6 ballots marked "not voting"; withdrawal of Standard Specifications C 64 – 28, 30 affirmative, none negative and 3 ballots marked "not voting"; Tentative Method of Test for Permanent Linear Change After Reheating of Refractory Brick (C 113 – 34 T), 32 affirmative, none negative and 1 ballot marked "not voting";: entative revision of Standard Method of Test for Refractory Materials Under Load at High Temperatures (C 16 – 20), 31 affirmative, 1 negative and 1 ballot marked "not voting"; revision of Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 – 33), 28 affirmative, 3 negative and 2 ballots marked "not voting"; revision of Tentative Specifications for Refractories for the Construction of Incinerators (C 106 – 34 T) and of Tentative Method of Test for Particle Size of Ground Refractory Materials (C 92 – 34 T), 31 affirmative, none negative and 2 ballots marked "not voting."

Tentative Method of Test for Permanent Linear Change After Reheating of Refractory Brick (C 113 - 34 T).—Since many specifications for fire brick contain a reheat test for which there has been no standard procedure, the committee deemed it advisable to recommend for publication as tentative a method of test for determining this property of refractories.

Tentative Revision of Standard Method of Test for Refractory Materials Under Load at High Temperatures (C 16 - 20).—There is a new type of fire brick being made that is known as super duty fire-clay brick. Since the regular standard load test is not severe enough to bring about very much deformation in this type of brick, the committee recommended that the new heating schedule be accepted as a tentative revision of the Standard Method C 16.

Tentative Revision of Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 - 33).—Although Pyrometric Cone No. 32½ has not been calibrated by the National Bureau of Standards it is needed in testing refractories and the committee accordingly recommended that this cone and its approximate end point be included in the cone table, published as a tentative revision of the Standard Method C 24.

Revision of Tentative Specifications for Refractories for the Construction of Incinerators (C 106 - 34 T).—In view of the fact that the standard size tolerances were inadvertently omitted from these specifications when they were presented for acceptance as tentative in the 1934 annual report, the committee recommended that a section on size tolerances be added to the specifications.

Revision of Tentative Method of Test for Particle Size of Ground Refractory Materials (C 92 - 34 T).—The Society has adopted Standard Specifications for Sieves for Testing Purposes (E 11 - 26) and since the Tyler standard sieve series is within the tolerances of these specifications and is a standard of the American Refractories Institute and widely used in the refractories industry, the committee recommended that both the A.S.T.M. series and the Tyler series be included in the Tentative Method C 92. Reporting of the sieve analyses was changed requiring the calculation to be reported to the nearest 0.5 per cent in place of 0.1 per cent.

RECOMMENDATIONS AFFECTING STANDARDS

New recommendations of the committee regarding standards and tentative standards under its jurisdiction are summarized below, together with the analysis of the letter ballot on each item.

I. Proposed Tentative Standard:

Proposed Tentative Definitions of Terms Relating to Refractories.—The committee recommends that the definitions of the terms, "insulating fire brick," "insulating brick," "calcining," "burning (firing)," "hard burned, medium burned, light burned," and "grog fire-clay mortar," as appended hereto,[1] be accepted for publication as tentative to be subsequently incorporated when adopted as standard in the Standard Definitions of Terms Relating to Refractories (C 71 - 31).

II. Proposed Revision of Standard:

Standard Definitions for Clay Refractories (*C 27 - 28*).[2]—The committee recommends that the following definition be accepted for publication as a tentative revision to be subsequently incorporated when adopted as standard in the Standard Definitions C 27:

> *Super Duty Fire-Clay Brick.*—The Pyrometric Cone Equivalent of super duty fire-clay brick shall not be lower than that of Standard Pyrometric Cone No. 33, when tested on the fired product. The alumina content shall be not less than 40 per cent. In the panel spalling test, these brick shall not lose more than 1.0 per cent. In the test for permanent linear change after reheating, schedule C, the brick shall not show more than 0.5 per cent shrinkage.

III. Adoption of Tentative Standards as Standard:

Tentative Definitions of Terms Relating to Refractories (*C 71 - 34 T*).[3]—No objections having been received during the past year to the tentative definitions of the terms, "silica fire clay," "ground fire clay" and "high-temperature bonding mortar," the committee recommends that these definitions be submitted to letter ballot of the Society for adoption as standard and added to the present Standard Definitions C 71 - 31.

Tentative Method of Chemical Analysis of Magnesite Refractories (*C 18 - 34 T*).[4]—The committee recommends that this tentative method be submitted to letter ballot of the Society for adoption as standard.

IV. Adoption of Tentative Revisions of Standards as Standard:

Standard Method of Test for Softening Point of Fire-Clay Brick (*C 24 - 33*).[5]—As no objections have been received during the year to the several revisions[6] of this standard, the committee recommends that these revisions, which cover Sections 1, 3, 5, 6 and the title of the specifications, as presented in the reports of the committee for 1931, 1932 and 1933, be adopted as standard.

Standard Definitions for Clay Refractories (*C 27 - 28*).[7]—No objections have been received during the year to the tentative revision[8] of these definitions, as presented in the 1933 report of the committee, which proposes that the term "softening point" be changed to "Pyrometric Cone

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[1] See p. 811.—ED.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 187.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 806 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 400.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 784 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 375.

[5] 1933 Book of A.S.T.M. Standards, Part II, p. 184.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1263 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1191.

[7] 1933 Book of A.S.T.M. Standards, Part II, p. 187.

[8] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1264 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1192.

Equivalent." The committee, therefore, recommends that this revision be adopted.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 36 members; 34 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Definitions of Terms Relating to Refractories (C 71 - 35 T):			
Insulating Fire Brick[a]	27	7	0
Insulating Brick[a]	28	6	0
Calcining	30	3	1
Burning (Firing)	31	2	1
Hard Burned, Medium Burned, Light Burned[a]	29	4	1
Grog Fire-Clay Mortar	32	0	2
II. PROPOSED REVISION OF STANDARD			
Standard Definitions for Clay Refractories (C 27 - 28):			
Super Duty Fire-Clay Brick[a]	23	5	6
III. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Definitions of Terms Relating to Refractories (C 71 - 34 T)	30	2	2
Method of Chemical Analysis of Magnesite Refractories (C 18 - 34 T)	28	0	6
IV. ADOPTION OF TENTATIVE REVISIONS OF STANDARDS AS STANDARD			
Method of Test for Softening Point of Fire-Clay Brick (C 24 - 33)	29	1	4
Definitions for Clay Refractories (C 27 - 28)	30	1	3

[a] The classified vote on the various definitions was as follows:

	Insulating Fire Brick		Insulating Brick		Hard, Medium and Soft Burned		Super Duty Fire-Clay Brick	
	Affirmative	Negative	Affirmative	Negative	Affirmative	Negative	Affirmative	Negative
Consumers	7	1	7	1	7	1	4	1
Producers	14	2	15	1	14	1	13	2
General Interests	6	4	6	4	8	2	6	2

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Tests and Specifications (M. E. Holmes, chairman):

This subcommittee has proposed new and revised tentative specifications for malleable iron furnace brick, stationary boiler furnace brick, and size tolerances for incinerator brick. It also proposed a tentative test for determining the permanent linear change after reheating refractory brick.

A study has been made by this subcommittee of the desirability of establishing a new series of Standard Pyrometric Cones with uniform temperature intervals and the question is now being given further consideration by the Standard Pyrometric Cone Co. The activities of the various sections of Subcommittee I are as follows:

Section on Abrasion (J. M. McKinley, chairman).—Two series of tests have been conducted on the abrasion of refractories and a proposed method of test has been laid out, but it has not advanced to the stage where it can be submitted to the Society for publication as tentative.

Section on Analysis (L. J. Trostel, chairman).—Following the suggestion of Committee E-1 on Methods of Testing, this section is making a critical examination of all the analytical methods under the jurisdiction of Committee C-8 in order to bring them up to date. It is also proposed to use a separate title for the method of analysis of each class of refractories.

Section on Load (C. M. Dodd, chairman).—This section prepared the heating schedule for testing super duty fire-clay brick issued as a tentative revision of the Standard Method C 16 as mentioned earlier in this report. A great deal of work was also done on the development of a new type load test furnace where the load is applied direct, instead of by levers. A further study is being made of this furnace.

Section on Microstructure (T. A. Klinefelter, chairman).—This section prepared recommendations for a standard procedure in the petrographic examination of certain types of refractories, and suggested the use of such data in specifications, but many members of the committee believe that the petrographic microscope is more of a research tool than a piece of analytical equipment. However, the proposal is receiving the consideration of the entire committee.

Section on Precision and Tolerances (F. A. Harvey, chairman).—The Manual for Interpretation of Refractory Test Data has been thoroughly revised and condensed and has been published in the new volume of A.S.T.M. Standards on Refractory Materials.

Section on Temperature (F. H. Norton, chairman).—Although the National Bureau of Standards has not recognized officially Cone No. 32½ this subcommittee recommended that this cone and its approximate end point be included tentatively in the cone table as mentioned earlier in this report. A furnace is being developed for determining the P. C. E. of high-temperature refractories.

Section on Sieves (L. J. Trostel, chairman).—Since the Society has already adopted the U. S. Sieve Series as a standard, Committee C-8 has also adopted this same series for use in the Tentative Method of Test for Particle Size of Ground Refractory Materials (C 92 – 34 T), but has included the Tyler series along with the A.S.T.M. sieves, as this series is within the tolerances of the A.S.T.M. Standard Specifications for Sieves for Testing Purposes (E 11 – 26) and the Tyler series is a standard of the American Refractories Institute.

Subcommittee II on Research (S. M. Phelps, chairman):

The equipment for the panel spalling test has been redesigned, so that it will be less expensive to construct and require smaller space. Some change has been made in the principle of the cooling units and a rearrangement of the burners has given a more uniform temperature in the furnace. Some work has also been done in testing the brick laid as headers instead of stretchers.

Subcommittee III on Nomenclature (A. S. Watts, chairman):

This subcommittee has prepared the definitions, appended hereto,[1] for the terms "grog fire-clay mortar," "insulating fire brick," "insulating brick," "calcining," "burning," and "hard burned," and "super duty fire-clay brick" which are being recommended for publication as tentative.

Subcommittee IV on Industrial Survey (L. C. Hewitt, chairman):

The Industrial Surveys of Service Conditions of Refractories in Open-Hearth Practice, Malleable Iron Industry, Copper Industry, Lead Industry, and By-Product Coke Ovens were all revised and have been published in the Volume of A.S.T.M. Standards on Refractory Materials.

Subcommittee V, Editorial (L. J. Trostel, chairman):

A great deal of work was done by this subcommittee in revising, compiling, and editing the new manual known as A.S.T.M. Standards on Refractory Materials. It is now available for distribution.

Subcommittee VI on Heat Transfer and Refractory Insulation (R. H. Heilman, chairman):

Considerable work has been done by this subcommittee in studying the various methods of determining heat conductivity of refractory materials. The various methods give radically different results and a movement is now on foot to correlate the different methods so that better agreement may be obtained between the different laboratories.

Subcommittee VII on International Standards on Refractories:

This special subcommittee was appointed, with R. S. Bradley as chairman, to consider the advisability of Committee C-8 recommending American participation in the work of Committee No. 33 on Refractories of the International Standards Association. A recommendation to this effect was made by the subcommittee and has been referred to letter ballot of the main committee for approval.

This report has been submitted to letter ballot of the committee which consists of 36 members; 33 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. A. HEINDL,
Chairman.

C. E. BALES,
Secretary.

E. H. VAN SCHOICK,
Vice Chairman.

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[1] See p. 811.—ED.

REPORT OF COMMITTEE C-9
ON
CONCRETE AND CONCRETE AGGREGATES

During the year Committee C-9 on Concrete and Concrete Aggregates held one meeting on February 21, 1935, in New York City, preceded by a joint meeting of the Executive and Technical Subcommittees in Washington, D. C., on December 8, 1934.

The year's work has resulted in the preparation of three new tentative methods of test, revisions in two existing tentative methods, a proposed tentative revision in one standard method of test, and a recommendation for adoption as standard of one tentative specification with revision.

In addition, the following reports and papers were submitted by subcommittees and are also presented as appendices to this report:

> "A Statistical Study of Bulk Specific Gravity and Mechanical Analysis Tests of Fine and Coarse Aggregate," submitted by Subcommittee XI on Evaluation of Data.
>
> "Comparisons of Different Types of Specimens for Compression Tests of Mortar," prepared by H. J. Gilkey and H. Walter Leavitt, and also submitted by Subcommittee XI.
>
> "Methods of Test for Determining Volume Changes in Concrete," prepared by R. E. Davis and submitted by Subcommittee XVI on Elasticity and Volume Changes of Concrete.

The following new projects have been undertaken by the committee:

Effect of crusher dust in crushed stone on the quality of concrete,
Method of sampling wet concrete,
Method of measuring volume of wet concrete,
Correlation study of modulus of rupture tests on concrete beams.

Recommendations Affecting Standards

I. Proposed Tentative Standards:

Proposed Tentative Method of Making Compression Tests of Concrete Using Portions of Beams Broken in Flexure.—This tentative method is recommended for publication as tentative as appended hereto.[1] It was prepared by Subcommittee VII on Methods and Apparatus for Testing Concrete (A. T. Goldbeck, chairman), based upon work done at the Kansas

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[1] See p. 835.—Ed.

State College and by the Kansas State Highway Commission. C. H. Scholer assumed the leadership in the preparation of this tentative method.

Proposed Tentative Method of Determining Voids in Coarse Aggregate.—This tentative method, appended hereto,[1] was prepared by Subcommittee IX on Specifications and Methods of Tests of Aggregates (H. F. Clemmer, chairman). It is identical with the existing test for fine aggregate covered by the Standard Method of Test for Determination of Voids in Fine Aggregate for Concrete (C 30 – 22) with which it will be combined when finally adopted as standard. The committee recommends the appended method[1] for publication as tentative.

Proposed Tentative Method of Test for Amount of Material Finer Than No. 200 Sieve in Aggregates.—This tentative method was prepared by a Joint Conference Committee on Silt and Loam appointed by Committee D-4 on Road and Paving Materials and Committee C-9. A brief explanatory statement respecting the test has been included in the method. Committee C-9 was represented on the Conference Committee by L. W. Teller and A. T. Goldbeck. The method as appended hereto[2] is recommended for publication as tentative.

Committee C-9 believes that after additional data have been secured, this method may be substituted for existing requirements in certain specifications, resulting in withdrawal of the Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 21),[3] and Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 28).[3]

II. Revisions of Tentative Standards:

Tentative Method of Test for Soundness of Fine Aggregates by Use of Sodium Sulfate (C 88 – 32 T)[4] *and Tentative Method of Test for Soundness of Coarse Aggregates by Use of Sodium Sulfate (C 89 – 32 T).*[4]—These two existing tentative methods have been revised to include provisions for the use of magnesium sulfate in determining the soundness of coarse and fine aggregates, in addition to the use of sodium sulfate covered by the present methods. The revised methods were prepared by Subcommittee IX on Specifications and Methods of Tests of Aggregates (H. F. Clemmer, chairman) and are identical with the recently developed methods of test approved by the Committee on Materials of the American Association of State Highway Officials. The committee recommends that the revised methods appended hereto[5] be accepted for publication as tentative.

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[1] See p. 846.—ED.

[2] See p. 832.—ED.

[3] 1933 Book of A.S.T.M. Standards, Part II, pp. 950, 951.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 713, 717 (1932); also 1934 Book of A.S.T.M. Tentative Standards, pp. 484, 480.

[5] See pp. 842 and 837.—ED.

III. Proposed Revision of Standard:

Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 33).[1]—The committee recommends for publication as tentative the following revision of this standard method:

Section 2 (b).—Change to read as follows by the addition of the italicized word and figures and the omission of the word and figures in brackets:

> (*b*) Coarse aggregate, or a mixture of fine and coarse [aggregates] *aggregate*, weight in grams [3000] *10,000* times the size of the largest sieve required, measured in inches.

Section 5 (a).—Change from its present form: namely,

> 5. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Section 4. Sieving shall be continued until not more than 1 per cent by weight of the residue passes any sieve during 1 min.

to read as follows:

> 5. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Section 4. The sieving operation shall be conducted by means of a lateral and vertical motion of the sieve, accompanied by jarring action so as to keep the sample moving continuously over the surface of the screen. In no case shall fragments in the sample be turned or manipulated through the screen by hand. Sieving shall be continued until not more than 1 per cent by weight of the residue passes any sieve during 1 min. On that portion of the sample retained on the No. 4 sieve, the above described procedure for determining thoroughness of sieving shall be carried out with a single layer of material. When sieving machines are used, their thoroughness of sieving shall be tested by using hand methods of sieving as above described.
>
> NOTE.—When samples of fine aggregate contain more than 2 per cent silt it is recommended that the Tentative Method of Test for Amount of Material Finer than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117 – 35 T) of the American Society for Testing Materials[2] be made prior to, and on the same sample as, the sieve anaylsis.

IV. Adoption of Tentative Standard as Standard:

Tentative Specifications for Ready Mixed Concrete (C 94 – 33 T).[3]—The committee recommends that these specifications be revised as follows and submitted to letter ballot of the Society for adoption as standard:

In Sections 8, 9 and 14 change the term "surface-dried materials" to read "dry materials."

Section 10.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 10. When the quality of the concrete is specified in terms of the consistency and the quantity of cement per unit of volume of concrete, 1 cu. ft. of cement shall be considered to weigh 94 lb., and the ratio by weight of the fine aggregate to the fine plus coarse aggregate shall be such as to produce a plastic and workable mixture and shall not be greater than [0.55] *shown in Table I*, unless otherwise specified by the purchaser; except that this ratio may not apply to [light-weight] aggregates

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 240.

[2] See p. 832.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 703 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 459.

having specific gravities less than 2.2 or greater than 3.0. Under this clause the proportions of cement to aggregate shall not be stated.

Add the following table to this section:

TABLE I.—LIMITING RATIO OF FINE AGGREGATE TO FINE PLUS COARSE AGGREGATE.

Maximum Size of Graded Aggregate, in.	Maximum Ratio of Fine Aggregate to Fine Plus Coarse Aggregate
2	0.40
1½	0.45
1	0.50
¾	0.55
⅜	0.60

Section 13.—Add the clause "the entire contents of the hopper shall be completely discharged," to the second sentence after the word "materials."

Section 14.—In the second sentence change the phrase "suitable to the purchaser" to read "approved by the purchaser" and in the third sentence delete the word "surface" from the phrase "surface moisture."

Section 19.—Change the fourth sentence to read as follows by the addition of the italicized words and the omission of the words in brackets:

> The mixing time shall be measured from the time that all [dry materials] *cement and aggregates* are in the mixer.

Change the sixth sentence to read as follows by the addition of the italicized words and in the eighth sentence change the phrase "When the agitator is provided with mixing blades" to read "When the agitator is provided with *adequate* mixing blades":

> When the central mixing plant is depended upon for the complete mixing, the minimum mixing time for mixers of 1 cu. yd. capacity or less shall be *not less than* 1 min.; for larger capacities of mixers this mixing time shall be increased at the rate of 15 sec. *or more* for each cubic yard, or fraction thereof, additional capacity.

Section 20.—In the first sentence add the word "maximum" before the words "rated capacity." Change the fourth, fifth and sixth sentences to read as follows by the addition of the italicized words and the omission of the word in brackets:

> [Any] Additional mixing, *if any*, shall be done at a slower speed specified by the manufacturer for agitation. *Except as subsequently provided*, the truck mixer shall be equipped with a tank for carrying the mixing water; the water shall be measured and placed in the tank at the proportioning plant, unless the tank is equipped with an automatic measuring device of the required accuracy and capable of being locked. The mixing water may be added directly to the batch, except as limited by Section 22, *in which case a tank shall not be required.*

Section 22.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> 22. Concrete shall be delivered to the site of the work, and discharge from the hauling container shall be [begun] *completed* within a period of 1½ hr. after the intro-

duction of the mixing water to the [dry materials] *cement and aggregates*, or the cement to the aggregate [if] *when* the fine aggregate contains [surface] moisture in excess of 6 per cent by weight [or] *and* the coarse aggregate contains [surface] moisture in excess of 3 per cent by weight.

Section 28 (b).—In the table change the first figures of the second, third and fourth lines under the column headed "Total cubic yards of concrete delivered on job" from "100," "1000," and "2000," respectively, to read "101," "1001," and "2001," respectively.

V. Tentative Standards Continued as Tentative:

The following specifications and methods of tests which have been tentative for three or more years are being continued as tentative, for the reasons indicated:

Tentative Specifications for Concrete Aggregates (C 33 - 31 T).—Several changes in these specifications are under consideration upon which it has not yet been possible to make definite decisions.

Tentative Method of Making Flexure Tests of Concrete Using a Simple Beam With Center Loading (C 78 - 30 T).—This method was developed in connection with a similar method of the American Association of State Highway Officials and it is considered best to retain it as tentative until it can be made to coincide with the method of the American Association of State Highway Officials inasmuch as state highway departments are the principal users of the method.

Tentative Method of Routine Analysis of the Cement Content of Hardened Portland Cement Concrete (C 85 - 31 T) and the *Tentative Method of Test or Apparent Specific Gravity of Coarse Aggregates in a Saturated Condition (C 86 - 31 T)*.—These methods have not yet had sufficient trial to prove their worth and it is therefore recommended to continue them as tentative for another year.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 59 members; 42 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Method of Making Compression Tests of Concrete Using Portions of Beams Broken in Flexure	42	0	0
Method of Determining Voids in Coarse Aggregate	42	0	0
Method of Test for Amount of Material Finer than No. 200 Sieve in Aggregates	37	0	4
II. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Method of Test for Soundness of Fine Aggregates by Use of Sodium Sulfate (C 88 - 32 T)	35	2	5
Method of Test for Soundness of Coarse Aggregates by Use of Sodium Sulfate (C 89 - 32 T)	34	3	5
III. PROPOSED REVISION OF EXISTING STANDARD			
Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 - 33)	36	2	4
IV. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Specifications for Ready Mixed Concrete (C 94 - 33 T), as revised	38	**0**	**4**

This report has been submitted to letter ballot of the committee, which consists of 59 members; 42 members returned their ballots, of whom 41 have voted affirmatively, and 1 negatively.

Respectfully submitted on behalf of the committee,

R. W. CRUM,
Chairman.

R. R. LITEHISER,
Secretary.

REPORT OF SUBCOMMITTEE XI ON EVALUATION OF DATA

A Statistical Study of Bulk Specific Gravity and Mechanical Analysis Tests of Samples of Fine and Coarse Aggregate[1]

This statistical study of bulk specific gravity and mechanical analysis tests of fine and coarse aggregate was undertaken for the purpose of studying the variations in results obtained from a series of samples, each of which was taken independently, but by a procedure which would presumably secure a sample representative of the whole supply. The results are expected to yield information as to the degree of confidence which may be placed in results obtained from such a sample, and on the problem of the number of such samples that should be collected to secure reasonably accurate data on the supply as a whole.

The tests were made upon 100 samples each of Potomac river sand and gravel, collected by the following procedures:

> *Sand.*—The 100 samples of sand were collected by filling gallon cans from a barge of the Capital Materials Co. Each sample was collected by shoveling with the can, starting at the bottom of the pile and working to near the top. Succeeding samples were collected by the same procedure, moving a short distance away each time in such a way that the points of the collecting were well distributed over the barge. The cans full of sand were sealed to avoid the loss of moisture.
>
> *Gravel.*—The 100 samples of gravel each of about 20 lb. were collected on October 8, 1933, from a barge of the Capital Materials Co. Thirty samples were collected from each end of the barge, 30 in the middle and 10 from random locations and distributed throughout the barge load. In the case of the groups of 30 samples, 10 were collected near the bottom of the load, 10 at about the middle and 10 at the top. Each sample was obtained by random shovelfuls at the locations indicated.

Tests for apparent and bulk specific gravities as defined in the A.S.T.M. Standard Definitions of Terms Relating to Specific Gravity (E 12 - 27)[2] were used. In addition, tests of bulk specific gravities on the basis of weight of saturated surface-dry aggregate were made upon all samples. This report presents a discussion of the bulk specific gravity results. Mechanical analyses were made on all samples, and the results are discussed. All tests were made by an experienced operator using ordinary care in manipulation.

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[1] This report was prepared by H. W. Leavitt from report of tests made for Subcommittee XI by the Laboratory of the National Sand and Gravel Assn., Stanton Walker, Director. The tests were made by George Crum under the supervision of C. E. Proudley.

[2] 1933 Book of A.S.T.M. Standards, Part I, p. 969.

Absorption tests were made on all samples. In the case of the sand, the results were not very satisfactory and are not reported. The facts indicate a very poor possibility of getting an accurate value for percentage of absorption of such a non-absorptive sand as the Potomac river sand. Further studies should be made to determine the reliability of the absorption test of sand, and it is suggested that such a study should include sands having a wide range in absorption. The absorption data of the coarse aggregate are discussed.

BULK SPECIFIC GRAVITY OF FINE AGGREGATE

Determinations of bulk specific gravity were made upon each of the 100 samples of sand by each of four different methods:

1. Chapman flask.
2. Pycnometer.
3. Kerosine.
4. Volumetric flask.

The A.S.T.M. Standard Method of Test for Approximate Apparent Specific Gravity of Fine Aggregate (C 68 – 30)[1,2] was used for the Chapman flask determinations. The same flask was used throughout each of the 100 analyses.

The pycnometer method consists of placing 500 g. of saturated surface-dried sand in a pycnometer and determining the weight of water required to fill it to overflowing. The pycnometer is composed of a pint Mason jar, the screw cap of which is conical, with a $\frac{1}{4}$-in. opening at the top or smaller end of the cone. After determining the displacement, the sand is removed and is oven dried at about 108 C. and then weighed.[3]

$$\text{Bulk specific gravity} = \frac{\text{Oven-dry weight}}{\begin{array}{c}(500 + \text{Weight of pycnometer filled with water}) - \\ \text{weight of pycnometer filled with sand and water}\end{array}}$$

In determining the bulk specific gravity by the "kerosine method," 400 g. of oven-dry sand are placed in a 500-ml. volumetric flask and covered with 200 ml. of kerosine (sp. gr. 0.80) for at least 1 hr. The volume of a solution of NaCl required to fill the flask to the mark is previously determined. Care is exercised to eliminate all free kerosine by rolling and otherwise agitating the sand in the flask.

$$\text{Bulk specific gravity} = \frac{400}{\text{Volume of flask} - \text{volume of salt water added}}$$

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 242.

[2] This is the same as the "Bulk Specific Gravity" defined in the Standard Definitions of Terms Relating to Specific Gravity (E 12 – 27), see 1933 Book of A.S.T.M. Standards, Part I, p. 969.

[3] All weights in grams.

The fourth method of determining specific gravity was by the use of a 500-ml. volumetric flask. This procedure consists of introducing 400 g. of saturated surface-dry sand into a calibrated volumetric flask and measuring the volume of water that must be added to fill the flask to the mark. The flask when nearly filled is rolled and otherwise agitated to eliminate all entrained air before filling for the final reading. The difference between the volume of the flask as determined by calibration and the volume of water added is the displacement of the 400 g. of saturated surface dry sand. The sample of sand after determination of the displacement is removed carefully and dried in an oven at about 108 C.

$$\text{Bulk specific gravity} = \frac{\text{Oven-dry weight}}{\text{Volume of flask} - \text{volume of water added}}$$

For three of these methods, sample No. 1 represents the same sample of sand which was carefully split and divided into the required size for each of the methods. Sample No. 2 was treated in the same way as were all of the corresponding 100 samples of fine aggregate. The samples used in the volumetric flask method were re-used in the "kerosine method." Significant results are given in Table I.

TABLE I.—BULK SPECIFIC GRAVITY TESTS OF POTOMAC RIVER SAND.

	VOLUMETRIC FLASK METHOD	CHAPMAN FLASK METHOD	PYC-NOMETER METHOD	KEROSINE METHOD
Number of samples	100	100	100	100
Average value of bulk sp. gr.	2.60	2.61	2.603	2.616
Standard deviation, per cent	0.621	0.605	1.141	0.753
Number of determinations required for a 1 to 10 chance that the error of the average will not be greater than 0.77 per cent[a]	2	2	6	3

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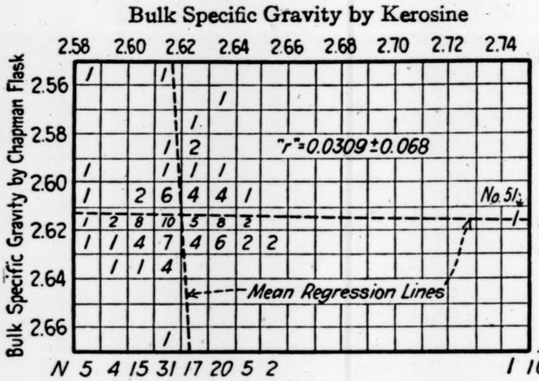
[a] An error of 0.77 per cent corresponds to a range in specific gravity of 0.02 from the mean. For method of determining chance, see Report on Significance of Tests of Concrete and Concrete Aggregates, p. 113, sponsored by A.S.T.M. Committee C-9 and published by the Society in pamphlet form in 1935.

STATISTICAL METHODS USED

In order to arrive at the factors which measure uniformity and also those which give the probability constants, it was necessary to determine the standard deviation. This may be obtained by squaring each deviation from the mean of the series, adding these results and finding their average, and then extracting the square root. In Table I, this value is also expressed as a percentage of the average of the series or population. For comparative purposes the standard deviation is often used as a measure of uniformity.

When the standard deviation is obtained in this way, no definite picture of the results is obtained, but by means of a scatter diagram (see Fig. 1) the actual dispersion of the results is graphically shown. The standard deviation is obtained from the data in a scatter diagram or correlation table as shown in Eqs. 2 and 4 in Fig. 1.

It will be noted (Eq. 2) that the standard deviation of the x array, or the bulk specific gravity by the "kerosine method," was found to be 0.0197 or 0.753 per cent of the mean, which is indicated in Eq. 1 (2.6155). This table also gives the mean and standard deviation of the y arrays on bulk specific gravity by the Chapman flask method. Equation 3 shows the method of obtaining the mean, which was found to be 2.6088; and Eq. 4,



N	ΣX	ΣX^2	ΣXY	$\Sigma X/N$	ΣY	ΣY^2
2	3	9	0	1.50	0	0
1	5	25	5	5.00	1	1
1	4	16	8	4.00	2	4
3	11	41	33	3.67	9	27
4	12	50	48	3.00	16	64
18	64	262	320	3.56	90	450
37	136	732	816	3.68	222	1 332
27	102	464	714	3.78	189	1 323
6	15	41	120	2.50	48	384
0						
0						
1	3	9	33	3.00	11	121
100	355	1649	2 097		588	3 706

$$\text{Mean } X = \frac{\Sigma X}{N} \text{ (Class Interval)} + \text{Origin} = \frac{3.55}{100}(0.01) + 2.580 = 2.6155 \qquad (1)$$

$$\text{S. D.}_x = \sqrt{\frac{\Sigma X^2}{N} - \left(\frac{\Sigma X}{N}\right)^2} \text{ (Class Interval)} =$$

$$\sqrt{\frac{1649}{100} - \left(\frac{355}{100}\right)^2}(0.01) = 0.0197 = 0.753 \text{ per cent} \qquad (2)$$

$$\text{Mean } Y = \frac{\Sigma Y}{N} \text{ (Class Interval)} + \text{Origin} = \frac{588}{100}(0.01) + 2.550 = 2.6088 \qquad (3)$$

$$\text{S. D.}_y = \sqrt{\frac{\Sigma Y^2}{N} - \left(\frac{\Sigma Y}{N}\right)^2} \text{ (Class Interval)} =$$

$$\sqrt{\frac{3706}{100} - \left(\frac{588}{100}\right)^2}(0.01) = 0.0158 = 0.605 \text{ per cent} \qquad (4)$$

$$\text{"}r\text{"} = \frac{\frac{\Sigma XY}{N} - \frac{\Sigma X}{N} \cdot \frac{\Sigma Y}{N}}{\sqrt{\left[\frac{\Sigma X^2}{N} - \left(\frac{\Sigma X}{N}\right)^2\right]\left[\frac{\Sigma Y^2}{N} - \left(\frac{\Sigma Y}{N}\right)^2\right]}} = \frac{\frac{2097}{100} - \frac{355}{100} \cdot \frac{588}{100}}{1.9717 \cdot 1.5766} = 0.0309 \pm 0.068 \qquad (5)$$

FIG. 1.[a]—A Scatter Diagram Showing Relation Between Bulk Specific Gravities of 100 Sand Samples as Determined by Two Methods of Test, Kerosine Method and Chapman Flask Method.

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[a] Truman L. Kelley, "Statistical Method," pp. 151–185, MacMillan Co., New York City (1929).
G. Udney Yule, "An Introduction to the Theory of Statistics," pp. 157–207, Charles Griffin and Co., Ltd., London (1929).

the method of obtaining the standard deviation, which has a value of 0.0158 or 0.605 per cent of the mean. Equation 5 shows the computation of the correlation coefficient, which in this case was found to be 0.0309 ± 0.068.

It will be noted that this value of *r* is practically zero, and this is as it should be, since the characteristics which tend to change the specific gravity results of each method are not different. In other words, because the material is the same on each of the 100 tests used in each of the two test methods, the results should all be identical; and if there were no personal equation or laboratory variants involved, all the results would show at the center of this diagram at the point indicated by the intersection of the mean regression lines, or roughly, in the squares adjacent to a gravity of 2.61. Possibly this could be better understood if the diagram were considered as a target with the bulls-eye located at the point 2.61. Unfortunately, all of the results do not hit the bulls-eye. One noticeably erratic result (test No. 51) which is found at the extreme right center of the diagram was undoubtedly due to a personal error in manipulation. The two results at the top of the diagram hit very wide and are probably due to some personal equation, as is also the one located in the bottom line of the diagram. These erratic results, however, should not be eliminated, because they are liable to occur in any series of this magnitude and, therefore, have a definite relation to the probability, or chance factors. The other correlation tables—five in number—are not presented here, but the correlation results are given in Tabel II.

TABLE II.—CORRELATION COEFFICIENTS, BULK SPECIFIC GRAVITY TESTS OF POTOMAC RIVER SAND.

	CHAPMAN FLASK	PYCNOMETER	KEROSINE
Volumetric Flask	0.36199 ± 0.0585	−0.14182 ± 0.0660	0.03296 ± 0.0675
Chapman Flask	....	0.03141 ± 0.0675	0.03088 ± 0.0675
Pycnometer	....	....	0.013567 ± 0.0676

It will be noted that most of the values for the correlation coefficient in Table II are very small, which accords with the previous explanation. By solving for the standard deviation in the two methods explained above, a check is obtained in each case. A graphical check of the accuracy of the work is also obtained by the passing of the mean regression lines (see Fig. 1) through the respective means of the two series of variables. In other words, in Fig. 1 it will be noted that these mean regression lines pass through or intersect at a point represented by 2.6155 on the *x* or horizontal axis and a point on the *y* or vertical axis located at 2.6088.

Another interesting thing to be noted in connection with Fig. 1 is that the mean regression lines are approximately at right angles to each other, indicating no appreciable value of ***r***. Had the series been composed of sands taken from different localities and having widely varying characteristics, the value of *r* would have been greatly increased and it would have approached a value of 1.00 for a perfect correlation. In the event of a perfect correlation, the mean regression lines would fall one upon the other and pass through the mean at a 45-deg. angle with the axes of the diagram. Such a theoretical diagram would show that a perfect correlation existed by the two methods, and that the same factors which tend to make a low specific gravity would be measured in the same degree by each of these two methods. A correspondingly high specific gravity would also be measured equally well by each of the two methods. Such data are not at hand at the present time.

BULK SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

One hundred samples of coarse aggregate or gravel were analyzed for specific gravity and absorption by the "wire basket" method and the "pycnometer" method.

TABLE III.—BULK SPECIFIC GRAVITY OF COARSE AGGREGATE.

	WIRE BASKET METHOD	PYCNOMETER METHOD
Number of tests	100	100
Average value (specific gravity)	2.558	2.555
Standard deviation, per cent	0.192	0.812
Number of determinations required for a 1 to 10 chance that the error of the average will not be greater than 0.77 per cent[a]	1	3

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[a] An error of 0.77 per cent corresponds to a range in specific gravity of 0.02 from the mean. For method of determining chance, see Report on Significance of Tests of Concrete and Concrete Aggregates, p. 113, sponsored by A.S.T.M. Committee C-9 and published by the Society in pamphlet form in 1935.

The "wire basket" method consists of immersing approximately 5000 g. of gravel (sizes finer than No. 4 sieve omitted) in a pan of water for at least 24 hr. The sample is transferred to the wire basket and its immersed weight determined. The entire sample is surface-dried by rolling on thick bath towels and quickly weighed to obtain the saturated surface-dried weight. The sample is then dried to constant weight in an oven at 108 C. The following computations were made:

$$\text{Absorption, per cent} = \frac{\text{Surface-dry weight} - \text{oven-dry weight}}{\text{Oven-dry weight}} \times 100$$

$$\text{Bulk specific gravity} = \frac{\text{Oven-dry weight}}{\text{Surface-dry weight} - \text{immersed weight}}$$

The temperature of the immersion water was 25 C. in nearly every instance.

In the "pycnometer method," approximately 1000 g. of saturated gravel are placed in a 1-qt. Mason jar with special conical screw cap (as recommended by the American Association of State Highway Officials in U. S. Department of Agriculture, *Bulletin No. 1216*, revised 1928, p. 23) filled with water and weighed. The difference between the weight of the pycnometer filled with water plus the weight of the gravel and the weight of the pycnometer filled with the gravel sample plus sufficient water to fill the pycnometer is the weight of the water displaced by the gravel.

$$\text{Bulk specific gravity} = \frac{D}{P + S - W}$$

where D = oven-dry weight of gravel,
S = saturated surface-dried weight of gravel,
P = weight of pycnometer full of water, and
W = weight of pycnometer plus the sample plus sufficient water to fill the pycnometer.

$$\text{Absorption, per cent} = \frac{S - D}{D} \times 100$$

No corrections for effect of differences in temperatures have been made.

The results obtained from a statistical analysis of the specific gravity data are given in Table III.

The absorption tests on the gravel samples were more satisfactory than in the case of the fine aggregate, and the constants given in Table IV were obtained:

TABLE IV.—ABSORPTION OF 100 GRAVEL SAMPLES.

Maximum absorption, per cent	1.12
Minimum absorption, per cent	0.86
Average absorption, per cent	0.98
Standard deviation, per cent	5.75
Number of samples required for a 1 to 10 chance that the error will not be greater than 5.1 per cent[a]	4

[a] An error of 5.1 per cent represents a difference of 0.05 in the percentage of absorption.

The correlation coefficient obtained from the data concerning the two methods of determining specific gravity on coarse aggregate was found to be -0.076713 ± 0.0675. In this case, like the similar results in connection with the study of the 100 samples of sand, the coefficient is practically zero, indicating that the results were aimed at the same objective and that the variant factors were not important enough to cause a serious disagreement in the results.

MECHANICAL ANALYSIS DATA

Fine Aggregate:

A mechanical analysis determination was made upon each of the 100 samples of fine aggregate. The sand samples as taken from the stock pile were kept in air-tight tin cans until all tests were completed.

A 525-g. sample of the damp sand was taken from each can and oven dried to constant weight at approximately 108 C. It was then cooled and re-weighed. The difference between the original 525 g. and the final oven-dry weight was used to compute the percentage of moisture in the stock pile sample.

The dry samples were then passed through the same nest of sieves in a Ro-tap shaker for 15 minutes. Table V gives the results obtained from these 100 analyses.

It is believed this is the only instance where 100 samples of the same sand have been analyzed. Accuracy of statistical facts requires that the population, or number of individuals examined, should be as large as possible. Some statisticians believe that 60 individuals is about the smallest population worthy of consideration. In this case we have a greater number than 60 so the results in Table V should be very significant. The right-hand column shows the coefficient of variation, which is the name given by Pearson to the standard deviation divided by the mean.[1] It will be noted that these coefficients of variation in the last column range from 14 per cent for the No. 30 to No. 50 fraction to about 41.6 per cent for the No. 50 to No. 100 fraction.

TABLE V.—DATA FROM SIEVE ANALYSIS OF POTOMAC RIVER SAND.

	Maximum	Minimum	Range	Mean	Standard Deviation	Coefficient of Variation, Standard Deviation/Mean
Total moisture, per cent	4.7	0.8	3.9	3.311	0.64366	19.44
Passing $\frac{3}{8}$ in. and retained on No. 4, per cent	6.6	2.0	4.6	3.915	1.23681	31.59
Passing 4 and retained on No. 8, per cent	25.2	7.5	17.7	15.455	3.59288	23.25
Passing 8 and retained on No. 16, per cent	22.2	5.6	16.6	13.196	4.37391	33.15
Passing 16 and retained on No. 30, per cent	37.3	7.6	29.7	21.643	4.43965	20.51
Passing 30 and retained on No. 50, per cent	47.1	15.6	31.5	34.331	5.07870	14.79
Passing 50 and retained on No. 100, per cent	19.7	0.6	19.1	9.966	4.14676	41.61
Passing No. 100, per cent	2.5	0.1	2.4	1.494	0.51691	34.60
Fineness modulus	3.43	2.65	0.78	2.9762	0.15954	5.36

A 15-minute shaking period does not seem always sufficient to get a thorough separation through the No. 100 sieve. This is especially true when the sand particles are slightly angular and the very small openings in the sieve become temporarily clogged. Great care, of course, is always necessary in order to get the sieve clean after each use. Undoubtedly, the high result in this series of tests may have been due to this difficulty with a sieve of such small openings.

In most laboratories, the fine aggregate is first sieved through a No. 4 sieve. Therefore, in the case of the four remaining sizes—Nos. 8, 16, 30, and 50—the values for the coefficients of variation will range from 14.8 to 33.2 per cent. It seems that using these four sizes as our criterion, we may safely state that a 25 per cent variation in the coefficient would be reasonable. In other words, if two samples of the same sand were given a mechanical analysis study and the average of the coefficients of variation for the various sieve sizes Nos. 8, 16, 30, and 50 did not exceed 25 per cent, a good measure of the mechanical analysis would be obtained. If the variation is more than 25 per cent, successive determinations should be made until this limit is reached.

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[1] Karl Pearson, "Tables for Statisticians and Biometricians," p. 18, London (1914).

If the laboratory technicians are willing to accept the fineness modulus as an adequate factor for expressing the size complex, these data show that in cases where the $\frac{\text{standard deviation}}{\text{mean}}$ of any series of tests does not exceed 5 per cent, the results are as accurate as would be expected from 100 analyses.

The field moisture content is, of course, quite variable and to a large extent dependent upon the granularmetric and mineralogical composition of the sand examined. In the case of the Potomac river sand the coefficient of variation is approximately 19.5 per cent. It is questionable whether this figure could be used as a criterion of variability in connection with other sands of different mineralogical composition.

TABLE VI.—DATA FROM SIEVE ANALYSIS OF POTOMAC RIVER GRAVEL.

	Maximum	Minimum	Range	Mean	Standard Deviation	Coefficient of Variation, Standard Deviation/Mean
Passing 1 in., retained on $\frac{3}{4}$, per cent	11.2	0.0	11.2	4.259	2.42831	**57.02**
Passing $\frac{3}{4}$ in., retained on $\frac{1}{2}$, per cent	39.8	5.3	34.5	19.617	6.42908	**32.77**
Passing $\frac{1}{2}$ in., retained on $\frac{3}{8}$, per cent	49.2	24.8	24.4	35.456	3.61580	10.20
Passing $\frac{3}{8}$ in., retained on $\frac{1}{4}$, per cent	48.0	18.1	29.9	35.718	6.08552	17.04
Passing $\frac{1}{4}$ in., per cent	13.7	0.8	12.9	4.950	2.50078	50.52
Fineness modulus	6.41	5.89	0.52	6.1901	0.86965	14.05

Coarse Aggregate:

For these analyses, 100 samples of gravel weighing about 30 lb. each were stored in sacks in the laboratory for about three months before the tests were begun. A sieve analysis was made of the entire sample in each instance. When the analyses were made, the samples were in an air-dried condition.

Square-opening sieves of 20-in. diameter were used. These were shaken by means of a foundry riddle at what appeared to be the most efficient speed. The shaking period was about three minutes in each case. Weighings were made on a 350-lb. capacity platform scale graduated to 0.01 lb.

The results of this study are given in Table VI, and the information is similar to that in Table V relating to fine aggregate. It will be noted that the largest and the smallest sizes gave the greatest variation as expressed in the coefficient of variation. For the size passing the 1-in. and retained on the $\frac{3}{4}$-in. sieve, this factor is 57 per cent; and for the material passing the $\frac{1}{4}$-in. sieve, this factor is 50.5 per cent. Disregarding these two, the range still goes from 10 to 33 per cent. The ranges are much more erratic than they were in the case of the fine aggregate. This would be expected in view of the differences in the characteristics of the two materials.

The subcommittee is rather loath to draw any general conclusions from these data. It may be safe to make the following statement: If 100 samples of gravel are passed through the sieves shown in Table VI, the fineness moduli will probably not show a coefficient of variation greater than 14 per cent.

SUMMARY AND CONCLUSIONS

1. The average values of bulk specific gravity as obtained upon 100 tests of the same sand by means of the volumetric flask, the Chapman flask, the pycnometer, and the "kerosine method" should agree very closely.

2. On a small number of determinations, the accuracies of the volumetric flask and the Chapman flask should be about equal.

3. The number of determinations required for a 1 to 10 chance that the error of the average will not vary more than 0.02 specific gravity are 2 in the cases of the volumetric flask and the Chapman flask, 3 in the case of the "kerosine method," and 6 in the case of the pycnometer method.

4. If 100 specific gravity determinations are made on a sample of gravel by the wire basket or the pycnometer method, the average values of specific gravity obtained will be practically identical.

5. The number of determinations required for a 1 to 10 chance that the error of the average specific gravity will not vary more than 0.02 are 1 test for the wire basket and 3 tests for the pycnometer method.

6. The average coefficient of variation to be expected on 100 tests of mechanical analysis of a fine aggregate on material passing the No. 4 and retained on the No. 50 sieve should not exceed 25 per cent.

7. The material retained on the No. 100 sieve and passing the No. 50, and the material passing the No. 100 should be expected to give higher variations than the portions retained on the larger sieves. The coefficients of variation of these sizes were found to be approximately 42 per cent for the material on the No. 100, and 34.5 per cent for material passing the No. 100 sieve.

8. The coefficient of variation of the fineness modulus as obtained upon the 100 samples of sand was 5.4 per cent.

9. The coefficient of variation of the fineness modulus obtained upon the 100 samples of gravel passing the 1-in. sieve was 14.1 per cent.

10. Individual sizes gave a large range in coefficients of variation on 100 samples of Potomac river gravel.

Respectfully submitted on behalf of the subcommittee,

H. WALTER LEAVITT,
Chairman.

APPENDIX I

COMPARISONS OF DIFFERENT TYPES OF SPECIMENS FOR COMPRESSION TESTS OF MORTAR

By H. J. Gilkey[1] and H. Walter Leavitt[2]

Synopsis

The use of a 2 by 2 by 4-in. prism, to be cast on its side against plane faces has been suggested as a specimen for compression tests on portland-cement mortar mixtures. Present practice is more or less deadlocked between the use of the 2-in. cube and the 2 by 4-in. cylinder. This paper reports tests on rather large numbers of cubes, cylinders and prisms. Relatively large multiple-specimen batches were used which necessitated special precautions to insure adequate control of recognized or possible variables. Among these were the effects of variable time lapse between mixing and placing, segregation, evaporation prior to casting, etc. Cubes were also capped and tested vertically as cast to detect possible effects of water-gain. The effect of overpouring or heaping specimens as a means of reducing the water-gain effect was investigated rather fully. The tests indicate that the prism may be expected to give the same quality indications as would the cube or the cylinder and that the strengths will be almost identical with those obtained from either cubes or fragments of beams tested as modified cubes.[3]

This last is an important consideration where both flexural and compressive strengths are observed as in the highway field. They also indicate that the multiple-specimen batch is, with suitable precautions, well adapted for tests, such as these, which require large numbers of companion specimens. Some consideration is given to the matter of uniformity as indicated by standard deviations and coefficients of variation. The results show satisfactory uniformity and the findings are consistent one with another.

The project was designed primarily to secure evidence on questions such as those raised in the discussion entitled "Cylinder *Versus* Cube *Versus* Prism as the Compression Test Specimen for Mortars,"[4] appearing in the December, 1934, *Bulletin* of the Society.

It was expected that the differences sought would be small and that unless the comparisons were based upon results from rather large numbers of companion specimens, experimental variations might cover up basic trends. This need for unusual numbers of duplicate specimens stamped the project as one of interest to Subcommittee XI on Evaluation of Data of Committee C-9 on Concrete and Concrete Aggregates which was in need of data from groups of 60 or more companion specimens and the project was planned, therefore, to serve a dual purpose.

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[2] Secretary, Maine Technology Experiment Station, University of Maine, Orono, Me.

[3] L. H. Koenitzer, "Proposed Method of Making Compression Tests on Portions of Concrete Beams from Flexure Tests," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 406 (1934); also *Bulletin No. 34*, Engineering Experiment Station, Kansas State College (1935).

[4] H. J. Gilkey, "Cylinder *Versus* Cube *Versus* Prism as the Compression Test Specimen for Mortars," published in *Bulletin No. 71*, Am. Soc. Testing Mats., December 31, 1934, p. 5.

The usual procedure in concrete investigations has been to weigh out, mix and cast each specimen individually or at most to include only a few specimens in a batch. In these tests the entire lot of specimens cast on any one day was from a single large batch. Thus the differences between companion specimens of a day's casting may be due not only to the usual unclassified variables but also to any of the following:

1. Lack of uniformity attained in mixing.
2. Segregation during the interval between mixing and casting.
3. The variable time that elapsed between the initial mixing of the batch and the molding of a particular specimen or group of specimens.

In a similar manner the differences between specimens from different batches might be due to:

1. Mistakes or other inaccuracies in proportioning the batches.
2. Variations in the materials entering the different batches (differences in the grading of the sand or in the quality or properties of the cement).
3. Environmental factors such as differences in temperature of air in laboratory or in mixing water, or in curing conditions for different batches.
4. Non-uniformity in the technique of mixing or of placing for the different batches.

Obviously, each of the two methods has its disadvantages but it is believed that each has a definite field of usefulness. Of course, the large or multiple-specimen batch is suitable only for those tests in which a considerable number of duplicate specimens is required. It may be that these specimens are to be subjected to different curings, exposures or other treatments subsequent to casting, or it may be, as in this case, that a large number of tests are desired on specimens that are presumably identical. A single error in weight or the introduction of any other important variable might invalidate a comparison between specimens of different batches, whereas a similar error would produce a single erratic result in a single-specimen batch. On the other hand the specimens from a multiple batch should still be comparable one with another. The obvious saving in "the overhead of fabrication" attainable through the use of multiple-specimen batches establishes the desirability of comparative studies to determine more fully their adaptations and limitations. In planning the tests this need was recognized as a secondary objective of the investigation.

Cognizance was taken of the following as actual or potential variables, and the precautions taken either to eliminate them or to measure the extent of possible resultant variability are indicated:

1. Possible non-uniformity of materials.

The cement consisted of one lot of ten sacks of Hawkeye cement purchased in the open market, thoroughly premixed, and stored in four paper-lined galvanized iron cans with close-fitting covers. Scoopfuls of cement were taken from each of the ten sacks in rotation and after a thorough mixing the four cans were filled by successive scoopfuls placed in rotation.

The aggregate consisted of one lot of Des Moines River natural sand of 0 to No. 4 grading. This was thoroughly air-dried and stored in one bin. Samples of the sand were taken for sieve analysis at the time each batch was weighed out.

2. Proportioning batches.

The proportions were 1:2.75 by weight with a gross or nominal water-cement ratio of 0.80 (0.53 by weight). No water was added to allow for absorption by the aggregate and the net or true water-cement ratio was somewhat less, possibly 0.75 (about 0.50 by weight). All measurement (including water) was by weight to the nearest 0.01 lb.

3. Mixing and environmental factors.

Mixing was accomplished in a motor-driven "Little Wonder" mixer of about 2 cu. ft. capacity. Initially the mixer was clean and dry. The mixing time was intended to be sufficient to insure adequacy as judged by the appearance of the batch, with the leeway in favor of overmixing rather than undermixing. In no case was the mixing time less than 5 min.

Table I supplies the essential information regarding the batches. The properties of the plastic mixture showed excellent uniformity between batches within the range of discrimination afforded by comparisons of slump and unit weights. For several batches additional slump and unit weight determinations were made near the middle and toward the end of the casting period. These were in close agreement with those recorded in Table I and supply no indication of change in the properties of the batches during the casting interval of from 1.3 to 2.6 hr. (Table I).

The only visible environmental difference between batches Nos. I to V was the temperature of the laboratory during the period of fabrication. While the 75 F. temperature for batch No. I might account for its apparent lack of strength in comparison with the other batches (see Table III), the 80 F. temperature for batch No. II hardly accounts for its excess of strength over the other batches with temperatures up to 85 F. For batches Nos. I and II there were also present minor differences in mixing techniques as will be apparent from the following descriptions.

TABLE I.—DATA ON THE BATCHES.

Item	Batch No. I	Batch No. II	Batch No. III	Batch No. IV	Batch No. V
Date cast	July 6, 1934	July 7, 1934	July 9, 1934	July 10, 1934	July 11, 1934
Laboratory temperature, deg. Fahr.	75	80	82	85	85
Total weight of batch, lb.	300	300	300	150	330
Volume of batch, cu. ft.	2.12	2.12	2.12	1.06	2.33
Initial slump, in.	10.0	10.8	10.3	9.3	10.0
Initial unit weight, lb. per cu. ft.	141.2	142.7	141.9	141.5	142.2
Finished casting, hr.	2.6	2.3	2.3	1.3	1.8
Struck off "B" specimens, hr.	5.0	4.0	5.0	1.5	5.5
Capped cylinders, hr.	6.0	5.0	8.0	3.0	7.0

Batch No. I.—The sand and cement were first mixed dry, after which all the water was added. This produced sticking to the drum but satisfactory mixing action was obtained by loosening up the batch with a trowel.

Batch No. II.—The sand and water were placed in the drum of the mixer and the dry cement was added in three lots with the drum revolving. This arrangement was very poor since it caused the cement to lump badly. The lumps were broken up by sifting the material through the fingers and satisfactory mixing was procured.

Batches Nos. III, IV, and V.—Same procedure as for batch No. I, except that water was added slowly as the drum revolved. This method was entirely satisfactory. Batch No. V was slightly larger than should be attempted in this mixer, however. As might be expected, batch No. IV required less mixing time than any of the others on account of its smaller size.

4. Casting, storage and testing.

As soon as a batch was mixed, observations were made for unit weight and slump. A measure of 2 l. (0.07 cu. ft.) was used for the unit weight determinations on the batches.

The mixture was intentionally fluid in order that casting could proceed rapidly by pouring. Molds were filled in stages of about one-third their height, the material being tamped lightly with a round wooden rod. For the pouring, a 1-gal. can was bent to a pouring V. With a scoop the can was filled about two-thirds full with mortar from the mixer drum and was passed rapidly from mold to mold. With the exception of the 3 by 6-in. cylinder molds, the briquets, and some of the cubes, all specimens of a type were cast in rapid succession and within a single five or ten-minute period. After the deposition of a layer in a group of molds the tamping was done for all by passing rapidly from one to another, after which the next layer was deposited.

The mixture held together well but whenever there was a visible gathering of water on the surface of the batch, the mixer drum was revolved for a few seconds to restore uniformity. Excess mixing was avoided at these periodic intervals to make negligible the grinding action which is known to accompany mixing and which assumes increasing importance as mixing is prolonged.

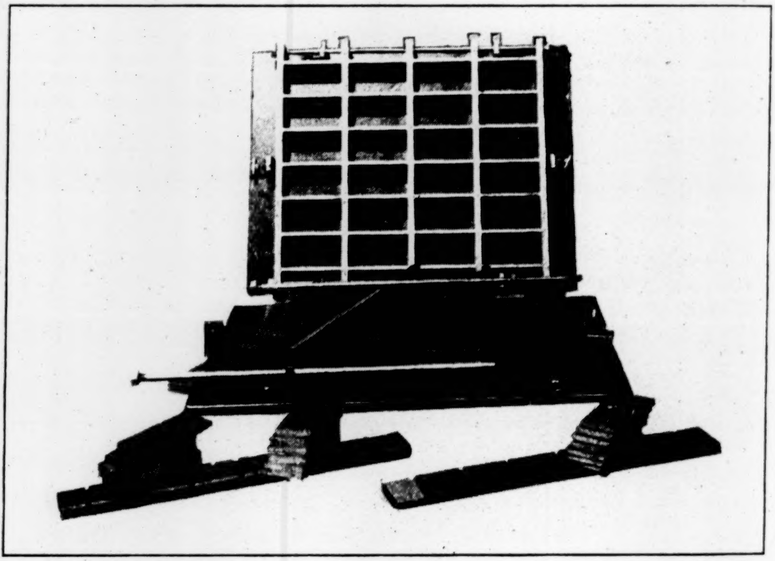

FIG. 1.—Two 24-Gang Prism Molds Showing One Assembled.

Specimens were covered with moist cloths a few moments after casting. The cloths did not drip on the mortar, nor were they in contact with it. All specimens which were to be tested vertically as cast were capped with neat cement from 5 to 8 hr. after mixing started, which was from 3 to 6 hr. after the last specimen was cast except for batch No. IV which was capped about 3 hr. after mixing started and less than 2 hr. after completion of casting. This batch was a little softer than it should have been when capped.

All cylinders were capped. In addition, 40 of the cubes of batch No. III were capped, 36 of which were tested vertically as cast. Otherwise all cubes and prisms were tested against a pair of plane faces which were lateral as cast.

The molds were removed the day after casting and moist storage was by immersion until tested. Compressive tests were performed on a Southwark-Emery machine except for some of the supplementary tests at 7 days. No recognized variables existed in either the storage or test conditions.

The cylinder, cube and briquet molds were standard equipment. The briquet molds were in gangs of three or five and 51 of the cube molds were in gangs of three. An oiled paper was placed between the mold and the plate glass or machined iron base plate. While no other precautions were taken to make molds watertight, there was very little leakage of the molds.[1]

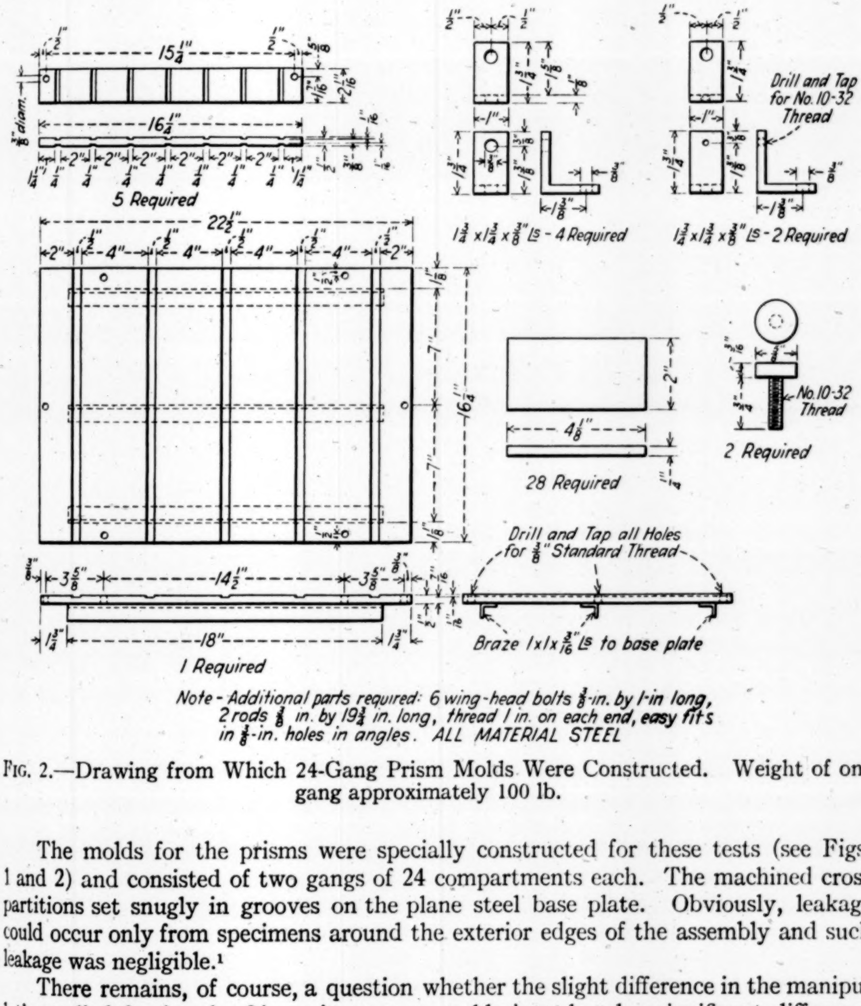
5 Required
1¾ x 1¾ x ⅜" Ls - 4 Required
1¾ x 1¾ x ⅜" Ls - 2 Required
Drill and Tap for No. 10-32 Thread
28 Required
No. 10-32 Thread
2 Required
1 Required
Drill and Tap all Holes for ⅜" Standard Thread
Braze 1 x 1 x 3/16" Ls to base plate
Note - Additional parts required: 6 wing-head bolts ⅜-in. by 1-in long, 2 rods ⅜ in. by 19¼ in. long, thread 1 in. on each end, easy fits in ⅜-in. holes in angles. ALL MATERIAL STEEL

FIG. 2.—Drawing from Which 24-Gang Prism Molds Were Constructed. Weight of one gang approximately 100 lb.

The molds for the prisms were specially constructed for these tests (see Figs. 1 and 2) and consisted of two gangs of 24 compartments each. The machined cross partitions set snugly in grooves on the plane steel base plate. Obviously, leakage could occur only from specimens around the exterior edges of the assembly and such leakage was negligible.[1]

There remains, of course, a question whether the slight difference in the manipulation called for by the 24-specimen gang molds introduced a significant difference in the quality of the hardened mortar. Of probable equal or greater importance is a natural difference that is prone to exist generally between the 2 by 4-in. cylindrical specimen and most others. The 2 by 4-in. cylinder mold is small of cross-section, deep and rather unstable, and unless special care is used in filling it, placement may be less perfect than for shallower, heavier molds such as those used for the cube, the side-cast prism or the briquet.[1]

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[1] Until the possible importance of leakage of water from the sides and around the bottoms of molds has been more definitely determined, it is desirable that leakage be avoided entirely which can be largely accomplished by pouring hot paraffin around the base. The authors question whether the importance of nominal leakage has not been overestimated. Much, if not all of the water that does so escape if from quiet filtration rather than agitation or excess working, would have gathered at the top of the specimen had it not found an outlet elsewhere. The extraction of water from the molded specimen assumes importance to whatever extent the solid particles are brought closer together thereby. A natural separation or sedimentation occurs in any mixture while it is plastic regardless of whether the water that oozes out escapes downward, upward or laterally. See discussion by H. J. Gilkey of paper by F. R. McMillan, "Suggested Procedure for Testing Concrete in Which the Aggregate Is More Than One-Fourth the Diameter of the Cylinders," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 534 (1930). The whole question of nominal leakage *versus* watertight molds needs further experimental study, however.

While the larger cylinders such as the 3 by 6-in. or 6 by 12-in. are of the same relative proportions, as the 2 by 4-in. the additional cross-sectional area and greater stability seems to promote better placement. On the other hand the amount of working per unit volume of material is apt to be greater for small specimens. It is such opposing factors as these that probably give rise to conflicting evidence on possible effect of size of cylinder on the compressive strength of a mortar or a concrete. Overworking promotes segregation by bringing water to the surface which lowers the voids and the water-cement ratio of the mass. If anything, the 2 by 4-in. cylinders of these tests were under-worked.

OUTLINE AND DISCUSSION OF THE TESTING PROGRAM

The primary purpose of the tests was to compare the 2 by 2 by 4-in. prism with both the 2-in. cube and the 2 by 4-in. cylinder as a compression test specimen for cement mortars. The more obvious advantages of the prism are:

(*a*) It can be cast horizontally against two plane ends, just as the cube is cast, and the need for capping or grinding to a plane the top surface (as cast) is thereby eliminated.

(*b*) The ratio of height to lateral dimension (as tested) is the same as that for standard cylinders. The measurement of strains is possible and the two end shear cones can develop without overlapping.

The question now arising is "What constitutes a proper measure of relative excellence? After the data are procured how is one to decide which of the several types is to be considered the best form of specimen?" Evidently those data are most pertinent which tend to supply answers to the following questions:

1. How do strengths as obtained from tests on prisms compare with those from tests on cubes or on cylinders?

2. Do tests on companion prisms give as uniform results as those on cubes or cylinders?

3. When concretes or mortars of different batches, ages, proportions, etc., are compared, will the observed differences in properties be essentially the same in magnitude or in kind as when the mixture is represented by a cylinder or by a cube?

The relatively large number of 28-day tests on prisms, cubes and cylinders supplies evidence bearing on questions 1 and 2. Question 3 is answered in part by the fact that the specimens reported represent five different batches mixed on different days. Brief reference is also made to two other batches by a different operator. Usually different portland-cement mixtures do exhibit parallel characteristics under similar conditions. Moreover, the supplementary tests at 7 days supply some additional evidence on the extent to which the main 28-day tests may be accepted as representative of mixtures in general.

There were several other extensions of the tests, two of which relate to the phenomenon of water-gain.[2] To whatever extent water-gain introduces variation in the quality of the material in successive horizontal layers, as cast, there will probably be differences in the stiffness of parallel vertical layers of a specimen which is tested on its side. Thus a load applied along the geometric axis is not collinear with the axis of resistance which should be located somewhat nearer the base of the specimen as cast.

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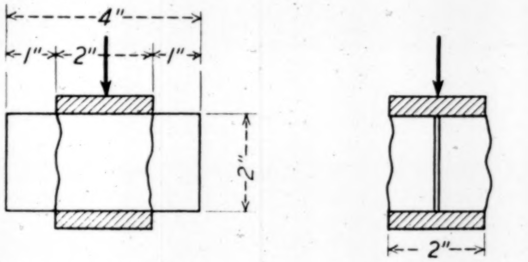
[1] Generally speaking, results from briquets are not apparently very significant or useful as checks on compressive behavior and the briquets of these tests are more or less an incidental feature.

[2] H. J. Gilkey, "Water-gain and Allied Phenomena," *Engineering News-Record*, Vol. 98, February 10, 1927, p. 242.

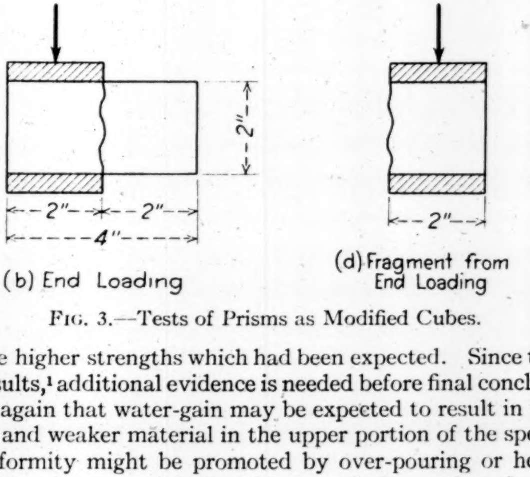
Twelve of the capped cubes were tested at 7 days and 28 others were tested at 28 days vertically as cast. Of the 7-day tests only 8 were vertical as cast, since it seemed desirable to test 4 of the capped specimens on their side, in the usual manner for cubes, as a check on any discernible influence that the neat cement cap might have on the test behavior. There is no indication that the thin cap influenced the strength of the 4 side-tested specimens within the limits of variation for the tests.

As will be noted further in discussing the results of the tests, the interesting and probably correct discovery was made that vertical testing seems to result in lower rather than in the higher strengths which had been expected. Since this is contrary to other reported results,[1] additional evidence is needed before final conclusions are drawn.



(a) Center Loading

(c) Fragments from Center Loading



(b) End Loading

(d) Fragment from End Loading

FIG. 3.—Tests of Prisms as Modified Cubes.

Recognizing again that water-gain may be expected to result in wetter and therefore more porous and weaker material in the upper portion of the specimen, it seemed possible that uniformity might be promoted by over-pouring or heaping the molds and striking off the excess material after the water had ceased to rise, that is after the initial slight stiffening that marks the end of the sedimentation stage, or downward working of solid particles.

Because the problem of water-gain appeared to be such a pertinent factor in the testing of side-cast specimens, it was decided to heap alternate molds or gangs of molds at the time they were filled and to strike them off just prior to the capping operation.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 200 (1925).

This was done and all specimens in columns headed B in Tables II, V, VI, VII, and VIII were accorded this treatment. All of the specimens accorded treatment A were struck off flush in the usual manner as the molds were filled.

It will be recalled that the 2 by 2 by 4-in. prisms were cast in two gangs of 24 compartments each. At each pouring these two gangs were filled at the same time by alternating the scoops of material in the filling process. One gang was struck off flush at the time of filling and the other was heaped and struck off later. In all cases every precaution was taken to insure that similar material went alternately into the molds that were finished flush and those that were heaped.

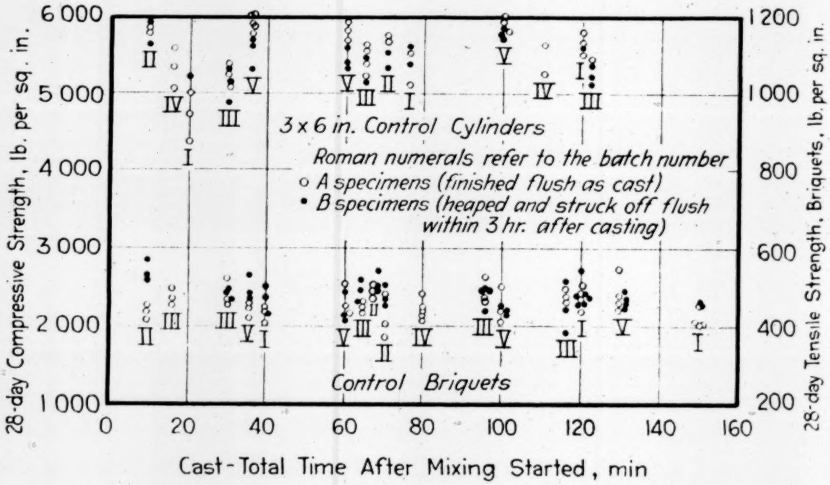

FIG. 4.—Results on 28-day Tests of Control Specimens.

Again the results were not according to expectations. As is apparent in the tabular record, there appears to be no consistent difference in strengths obtained from specimens accorded treatment A (those finished flush) and those accorded treatment B (those heaped and struck off later).[1]

A digression was made into the field of the modified cube method for obtaining compressive data from fragments of beams.[2]

Figure 3 shows diagrammatically the different types of modified cube tests which were made. In all cases the specimens were tested under a carefully centered spherical head as in the other compression tests.[3]

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[1] For some of the batches the scrapings from the "B" specimens were vigorously remixed (by hand with a trowel) and were cast into 3 by 6-in. cylinders and briquets. The casting of the scrapings occurred from 1.6 to 5.6 hr. after mixing started and from 0.3 to 2.3 hr. after the casting was completed. The heaped specimens of batches Nos. II and IV were scraped before initial stiffening had occurred and these specimens gave strengths comparable with those of the regular specimens. The other specimens cast from the scrapings were distinctly weaker. Batch No. V was scraped 5.5 hr. after mixing (3.7 hr. after casting) and the scrapings were too stiff to mold.

[2] L. H. Koenitzer, "Proposed Method of Making Compression Tests on Portions of Concrete Beams from Flexure Tests," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 406 (1934); also *Bulletin No. 34*, Engineering Experiment Station, Kansas State College (1935).

[3] The strength from the modified cube tests were practically identical with those from the regular cube tests and differed little, therefore, from the results of the prism tests. Of striking interest is the fact that all of the four types of test shown in Fig. 3 gave equal strengths with average deviations of about 5 per cent for a total of 12 tests at 28 days and 26 tests at 7 days. These findings are timely since they indicate that compressive strengths from cubes, prisms, and prisms as modified cubes are virtually the same. If, therefore, the prism were to replace the cylinder as the conventional compressive specimen, strengths from any of the three types of test would be directly comparable. Strengths obtained from fragments of tested beams would not require the use of a reduction factor as they now do to translate them into equivalent cylinder strengths.

A number of control features were introduced in addition to the observations of slumps and unit weights of the freshly mixed batches, which are recorded in Table I. The most important of these was the casting of seventy-two 3 by 6-in. cylinders, 61 of which were tested at 28 days and 11 of which were tested at 7 days (Table II). The control cylinders were cast at intervals as the molding proceeded. A few (usually six) were the first specimens cast. Another set of six was cast at about the middle of the casting period and a third set near the end. The briquets and some of the cubes were cast at similar intervals. The plotted strengths for all the 28-day 3 by 6-in. cylinder tests and also 28-day strengths for the briquet tests appear in Fig. 4 and indicate clearly that within the casting period there was apparent no tendency for specimens either to increase or decrease in strength as the time between mixing and placing increased. The results from the control cubes and from all three types of specimens at 7 days give the same indication and are not reproduced because Fig. 4 is so thoroughly representative. This finding is in accord with earlier results obtained by Gonnerman[1] and by the author[2] and is counter to apparent indications noted by Slater and Walker.[3] In another hour or two there could be expected a distinct reduction in strength whenever it became necessary to break up the initial set of the mortar in order to mold it. This was indicated by lower strengths obtained from specimens cast from the residue that was scraped from the B specimens as an unreported reconnaissance.

TABLE II.—ALLOCATION OF SPECIMENS.

Description	Test Age, days	Cast On	Batch Number and Casting Method										Totals		
			No. I		No. II		No. III		No. IV		No. V				
			A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A and B[a,b]
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.															
Cubes	28	side	33	27	29	31	10	10	44	..	26	30	142	98	240
Prisms	28	side	12	12	20	20	20	19	39	..	18	18	109	69	178
Cylinders, 2 by 4-in	28	end	11	11	11	10	11	9	9	11	8	5	50	46	96
Cylinders, 3 by 6-in. (controls)	28	end	6	6	6	4	9	9	3	..	9	9	33	28	61
Cylinders, 6 by 12-in. (controls)	28	side	1	1	1	1	1	1	..	..	1	..	4	3	7
Briquets (controls)	28	side	16	14	6	6	12	12	8	..	13	13	55	45	100
SUPPLEMENTARY TESTS AT 7 DAYS.															
Cubes	7	side	3	3	3	3	2	2	4	..	5	5	17	13	30
Prisms	7	side	2	2	2	2	1	1	4	..	2	2	11	7	18
Cylinders, 2 by 4-in	7	end	1	1	1	1	1	1	1	..	3	4	7	7	14
Cylinders, 3 by 6-in. (controls)	7	end	3	3	3	2	..	..	..	..	..	..	6	5	11
Briquets (controls)	7	side	10	9	4	4	8	8	4	..	6	9	32	30	62
MISCELLANEOUS TESTS															
Cubes capped (tested vertical)	28	end	..	..	..	..	16	12	..	..	..	..	16	12	28
Cubes capped (tested vertical)	7	end	..	..	..	..	4	4	..	..	..	..	4	4	8
Cubes capped (tested on side)	7	side	..	..	..	..	2	2	..	..	..	..	2	2	4

[a] Finished flush in usual manner.
[b] Heaped and struck off flush within 3 hr. after casting (see Table I).

On the other hand, if there were appreciable evaporation from the batch as it stood throughout the casting period, it goes without saying that correspondingly higher strengths should be obtained with the lapse of time (barring other compensating factors). To check this point, two 10-lb. lots of mortar from batch No. V were placed in ordinary 10-qt. galvanized iron pails which were weighed and set to one side at the beginning of casting. One pail was covered with a moist cloth and the other was left exposed to the air of the laboratory which was 85 F. (see Table I). Upon reweighing 5.5 hr. later both lots had stiffened decidedly and a little free water remained on the surface of each. The covered pail had lost no weight and the open pail had lost 0.03 lb. While even this small amount represents 2.4 per cent of the total water present in the 10-lb. lot of mortar which would amount to a strength differential of about 125 lb. per sq. in. at 28 days, the 5.5 hr. period of exposure was more than three times the length of the casting period for the batch (1.8 hr. see Table I) and it is apparent that for these conditions the effect of evaporation from the mixer drum during casting can be accepted as negligible. The surface-volume ratio was slightly greater for the material in the pail than for that in the mixer drum from which the evaporation should have been relatively less. Thus for indoor exposures under conditions of still air and average humidities a batch of mixed concrete or mortar can remain exposed for the full plastic range of time with little alteration in its water-cement ratio because of evaporation. If spread out rather thinly in a shallow pan, or with greater circulation of air, evaporation might be expected to assume greater importance. Actually, for the rather fluid mixture of these tests, evaporation had extracted no water from the mortar since there was still present on the surface some of the free water that had gathered from the natural sedimentation or plastic settling. Eventually this free water would all have returned to the interior of the mortar as drawn upon for hydration, which phenomenon has been observed experimentally and discussed elsewhere.[1] With a leaky container it is apparent that loss from leakage

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[1] H. F. Gonnerman and P. M. Woodworth, "Tests of Retempered Concrete," *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 361 (1929).

[2] Discussion by H. J. Gilkey of above paper, p. 380.

[3] W. A. Slater and Stanton Walker, "Report on Field Tests of Concrete Used in Construction Work," *Proceedings*, Am. Soc. Civil Engrs., Vol. LI, No. 1, January, 1925, p. 32.

TABLE III.—MEAN STRENGTHS—ALL BATCHES.

Description	Test Age, days	Cast On	Batch No. I	Batch No. II	Batch No. III	Batch No. IV	Batch No. V	Weighted Average	Standard Deviation		Total Tests
									Lb. per sq. in.	Per cent	
1	2	3	4	5	6	7	8	9	10	11	12
MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.											
Cubes	28	side	6040	6640	6370	5930	6300	6260	454	7.2	240
Prisms	28	side	5570	6880	5960	5720	6020	6070	610	10.0	178
Cylinders, 2 by 4-in.	28	end	4880	5810	5420	5090	5650	5350	427	8.0	96
Cylinders, 3 by 6-in. (controls)	28	end	5340	5670	5330	5360	5770	5520	302	5.5	61
Cylinders, 6 by 12-in. (controls)	28	end	5280	5820	5140	....	5300	5400	307	5.7	7
Briquets (controls)	28	side	460	500	480	460	460	470	67	14.3	100
SUPPLEMENTARY TESTS AT 7 DAYS											
Cubes	7	side	2980	2930	2860	2870	3110	2980	82	2.8	30
Prisms	7	side	2550	3290	2910	2770	2810	2860	296	13.5	18
Cylinders, 2 by 4-in.	7	end	2200	2710	2620	2410	2800	2650	192	7.2	14
Cylinders, 3 by 6-in. (controls)	7	end	2770	2840	....	....	....	2800	167	6.0	11
Briquets (controls)	7	side	320	360	340	340	320	330	29	8.8	62
MISCELLANEOUS TESTS											
Cubes capped (tested vertical)	28	end	....	....	5700	....	....	5700	426	7.5	28
Cubes capped (tested vertical)	7	end	....	....	2600	....	....	2600	274	10.5	8
Cubes capped (tested on side)	7	side	....	....	3000	....	....	3000	215	7.2	4

Remarks: Cubes of Line 14 similar to cubes of Line 7 except for cap on one side as tested.

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[1] Discussion by H. J. Gilkey of paper by F. R. McMillan, "Suggested Procedure for Testing Concrete in Which the Aggregate Is More Than One-Fourth the Diameter of the Cylinders," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 530 (1930).

TABLE IV.—BATCHES COMPARED ON BASIS OF PERCENTAGES OF MEAN STRENGTH FOR MAIN TESTS AND SUPPLEMENTARY 7-DAY TESTS.

Description	Test Age, days	Cast On	Total Tests	Weighted Average Strength (100 per cent)	Batch Number					Average Deviation, per cent
					I	II	III	IV	V	
1	2	3	4	5	6	7	8	9	10	11
PERCENTAGES FOR MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.										
Cubes	28	side	240	6260	96.5	106.1	101.8	94.7	100.6	3.7
Prisms	28	side	178	6070	91.8	113.3	98.2	94.2	99.2	5.9
Cylinders, 2 by 4-in.	28	end	96	5350	91.2	108.6	101.3	95.1	105.6	6.2
Cylinders, 3 by 6-in. (controls)	28	end	61	5520	96.7	102.7	96.6	97.1	104.5	3.6
Cylinders, 6 by 12-in. (controls)	28	end	7	5400	97.8	107.8	95.2	....	98.1	4.5
Briquets (controls)	28	side	100	470	97.9	106.4	102.1	97.9	97.9	2.6
Average percentages	..	....	...	....	95.3	108.2	99.8	94.9	100.7	3.8
PERCENTAGES FOR SUPPLEMENTARY TESTS AT 7 DAYS.										
Cubes	7	side	30	2980	100.0	98.3	96.0	96.3	104.4	2.8
Prisms	7	side	18	2860	89.2	115.0	101.8	96.8	98.2	7.0
Cylinders, 2 by 4-in.	7	end	14	2650	83.0	102.3	98.9	90.9	105.7	6.4
Cylinders, 3 by 6-in. (controls)	7	end	11	2800	98.9	101.4	....	....	....	1.2
Briquets (controls)	7	side	62	330	97.0	109.1	103.0	103.0	97.0	3.8
Average percentages	..	....	...	....	96.2	105.4	101.4	98.1	100.9	2.7

NOTES.—Column 11 is the mean of the deviations (from 100 per cent) of the preceding columns, weighted according to number of specimens in a batch (see Table II). These are deviations of batch averages expressed as percentages of mean strengths for all batches. For the standard deviations of specimens within the batches and for the averages of these for all the batches see Table VII. The standard deviations for all specimens of a kind, regardless of batch boundaries, are given as columns 10 and 11 of Table III and as columns 6 and 7 of Table IX.

TABLE V.—ALL MEAN STRENGTHS WITH BATCHES SUBDIVIDED TO SHOW EFFECT OF HEAPING.

Description	Test Age, days	Cast On	Batch Number and Casting Method										Weighted Averages		
			No. I		No. II		No. III		No. IV		No. V				
			A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	Mean
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.															
Cubes	28	side	5880	6230	6650	6640	6350	6400	5930	....	6380	6240	6170	6380	6260
Prisms	28	side	5570	5570	6910	6860	6070	5850	5720	....	6200	5840	6070	6090	6070
Cylinders, 2 by 4-in.	28	end	4880	4880	6000	5590	5500	5330	5030	5140	5540	5840	5400	5290	5350
Cylinders, 3 by 6-in. (controls)	28	end	5260	5420	5690	5640	5440	5220	5360	....	5900	5640	5570	5460	5520
Cylinders, 6 by 12-in. (controls)	28	end	5220	5340	5840	5800	5400	4880	....	....	5300	....	5440	5340	5400
Briquets (controls)	28	side	450	480	470	530	480	480	460	....	470	460	460	480	470
SUPPLEMENTARY TESTS AT 7 DAYS															
Cubes	7	side	2890	3060	2870	2990	2870	2850	2870	....	3220	3000	2980	2990	2980
Prisms	7	side	2520	2580	3240	3330	2890	2930	2770	....	3000	2620	2860	2860	2860
Cylinders, 2 by 4-in.	7	end	2210	2180	2850	2560	2740	2490	2410	....	2810	2800	2660	2630	2650
Cylinders, 3 by 6-in. (controls)	7	end	2780	2770	2920	2710	....	....	....	....	....	....	2850	2750	2800
Briquets (controls)	7	side	320	320	380	330	340	340	340	....	320	320	330	330	330
MISCELLANEOUS TESTS															
Cubes capped (tested vertical)	28	end	....	....	....	....	5840	5530	....	....	....	....	5840	5530	5700
Cubes capped (tested vertical)	7	end	....	....	....	....	2550	2640	....	....	....	....	2550	2640	2600
Cubes capped (tested on side)	7	side	....	....	....	....	3180	2810	....	....	....	....	3180	2810	3000

[a] Finished flush in usual manner.

[b] Heaped and struck off flush within 3 hr. after casting (see Table I).

would have exceeded the evaporation in this instance. The relative unimportance of the evaporation is in line with similar unpublished tests made a number of years ago under conditions even more favorable to evaporation losses than were these.

All specimens were weighed as removed from the molds and as tested. In addition, the seven 6 by 12-in. cylinders were weighed as cast and at other intervals. The weights at test (reduced to unit weight in pounds per cubic foot) are representative and are recorded in Table VIII. While the deviations are not shown for the weights it is evident at a glance that the extreme range is scarcely 2 per cent and the average deviation is therefore very small and much less than the percentage range in strengths obtained. It is scarcely to be expected that deviations so slight should bear any discernible relationship to the strengths obtained. The statistical study of the weight data indicates that little if any correlation does exist. Doubtless the conclusion to be drawn is that the small deviations noted were due in part to minor differences between the actual and assumed sizes of molds (and specimens) and partially to minor differences in the distribution of aggregate throughout the batch. Some specimens doubtless had a slightly higher-than-average ratio of sand to paste which would tend to

TABLE VI.—RESULTS FROM HEAPING—PERCENTAGES OF MEAN STRENGTHS FOR MAIN TESTS AND SUPPLEMENTARY 7-DAY TESTS.

Description	Test Age, days	Cast on	Total Tests	Weighted Average Strength (100 per cent)	Batch Number and Casting Method										Average Deviation, per cent		
					No. I		No. II		No. III		No. IV		No. V				
					A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A and B[a,b]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERCENTAGES FOR MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.																	
Cubes	28	side	240	6260	93.9	99.5	106.2	106.1	101.4	102.2	94.7	....	101.9	99.7	4.8	2.4	3.8
Prisms	28	side	178	6070	91.8	91.8	113.8	113.0	100.0	96.4	94.2	....	102.1	96.2	5.8	7.2	6.3
Cylinders, 2 by 4-in.	28	end	96	5350	91.2	91.2	112.1	104.5	102.8	99.6	94.0	96.1	103.5	109.1	6.9	5.1	6.0
Cylinders, 3 by 6-in. (controls)	28	end	61	5520	95.3	98.2	103.1	102.2	98.5	94.6	97.1	....	106.9	102.2	4.0	3.1	3.6
Cylinders, 6 by 12-in. (controls)	28	end	7	5400	96.7	98.9	108.1	107.4	100.0	90.4	....	....	98.1	....	5.8	6.0	4.5
Briquets (controls)	28	side	100	470	95.7	102.1	100.0	112.8	102.1	102.1	97.9	....	100.0	97.9	2.0	3.5	2.7
Average percentages	..	....	...	....	93.6	97.4	108.5	108.2	101.0	98.7	94.8	96.1	102.3	99.5	4.8	3.2	4.1
PERCENTAGES FOR SUPPLEMENTARY TESTS AT 7 DAYS.																	
Cubes	7	side	30	2980	97.0	102.7	96.3	100.3	96.3	95.6	96.3	....	108.0	100.7	4.8	1.6	3.5
Prisms	7	side	18	2860	88.1	90.2	113.3	116.4	101.0	102.4	96.8	....	104.9	91.6	6.7	10.0	8.1
Cylinders, 2 by 4-in.	7	end	14	2650	83.4	82.3	107.5	96.6	103.4	94.0	90.9	....	106.0	105.6	....	....	7.4
Cylinders, 3 by 6-in. (controls)	7	end	11	2800	99.3	98.9	104.3	96.8	....	....	....	....	....	....	....	....	2.2
Briquets (controls)	7	side	62	330	97.0	97.0	115.1	100.0	103.0	103.0	103.0		97.0	97.0	4.5	2.6	3.6
Average percentages	..	....	...	....	95.6	96.6	107.2	102.0	102.0	100.9	98.0	....	103.0	99.2	3.8	1.8	2.9

NOTES.—Columns 16, 17 and 18 are means of the deviations (from 100 per cent) of the preceding columns, weighted according to number of specimens in a batch (see Table II).

See notes under Table IV for further explanation and references to other deviations.

[a] Finished flush in usual manner.

[b] Heaped and struck off flush within 3 hr. after casting (see Table I).

increase the unit weight without necessarily altering the voids-cement or water-cement ratio. As an illustration, a concrete of a given water-cement or voids-cement ratio will have a unit weight considerably above that of its mortar of the same voids-cement or water-cement ratio.[1] Thus as an indication of uniformity these unit weight data are useful and satisfying, but beyond this they are probably not significant.

As an additional cross-check upon uniformity, stress-strain data were taken for all 28-day tests of 3 by 6-in. and 6 by 12-in. cylinders. These were obtained without stopping the testing machine or altering the rate or manner of loading in any way and showed that the stress-strain characteristics are very similar for all the specimens.

TABLE VII.—RESULTS FROM HEAPING—STANDARD DEVIATIONS EXPRESSED AS PERCENTAGES AND COMPARED FOR MAIN TESTS AND SUPPLEMENTARY 7-DAY TESTS.

Description	Test Age, days	Cast on	Total Tests	Weighted Average Strength (100 per cent)	Batch Number and Casting Method[c]										Average Standard Deviation, per cent[c]		
					No. I		No. II		No. III		No. IV		No. V				
					A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A and B[a,b]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERCENTAGE DEVIATIONS FOR MAIN TESTS AND CONTROLS. TESTED AT 28 DAYS.																	
Cubes	28	side	240	6260	7.2	4.0	5.1	5.0	5.4	4.7	4.8	[c]	4.6	9.5	5.4	5.3	5.3
Prisms	28	side	178	6070	4.4	3.7	6.5	5.5	5.4	5.6	4.2	—	4.2	6.5	4.8	5.6	5.1
Cylinders, 2 by 4-in.	28	end	96	5350	5.8	7.5	5.9	9.3	3.0	4.7	6.3	5.6	5.0	5.0	5.2	6.6	5.8
Cylinders, 3 by 6-in.	28	end	61	5520	9.5	4.7	3.9	3.5	2.4	3.2	3.8	—	1.9	2.1	3.9	3.2	3.6
Cylinders, 6 by 12-in.	28	end	7	5400	X[c]	X	X	X	X	X	—	—	X	—	X	X	X
Briquets	28	side	100	470	13.0	7.9	7.4	6.6	5.3	7.4	4.5	—	7.2	8.1	8.1	7.7	7.9
Average per cent deviations	..	....	...	....	7.9	5.4	5.8	5.8	4.5	5.3	4.7	5.6	4.7	7.4	5.5	5.7	5.6
PERCENTAGE DEVIATIONS FOR SUPPLEMENTARY TESTS AT 7 DAYS.																	
Cubes	7	side	30	2980	13.6	6.5	9.4	3.4	0.1	2.4	2.1	—	11.4	6.5	8.3	5.2	6.7
Prisms	7	side	18	2860	0.3	2.6	3.7	1.6	X	X	10.1	—	5.9	5.8	5.5	2.9	4.5
Cylinders, 2 by 4-in.	7	end	14	2650	X	X	X	X	X	X	X	—	1.5	2.6	1.5	2.6	2.1
Cylinders, 3 by 6-in.	7	end	11	2800	4.6	8.6	2.5	5.4	—	—	—	—	—	—	3.6	7.3	5.7
Briquets	7	side	62	330	7.3	6.7	7.0	7.0	6.4	6.1	6.4	—	5.2	8.8	6.4	7.3	6.8
Average per cent deviations	..	....	...	....	7.1	6.5	5.9	4.7	5.1	5.4	6.2	—	6.5	6.7	6.0	5.8	5.8

NOTES.—Columns 16, 17 and 18 are the averages of the deviations listed in the preceding columns weighted according to numbers of specimens represented. They are therefore the averages of the deviations within the respective batches expressed as percentages of weighted average strength for all batches. Note that the standard deviations for all specimens of a kind, regardless of batch lines appear in Table III, columns 10 and 11, and also in Table IX, columns 6 and 7.

[a] Finished flush in usual manner.

[b] Heaped and struck off flush within 3 hr. after casting (see Table I).

[c] A rule (—) = no specimen; X = A single specimen (no deviation).

As a final check on uniformity and repeatability, another operator (with an entirely different laboratory background) conducted some parallel tests. The same equipment was used and presumably the same specifications were followed. The specimens were fewer in number and some of the observations recorded in batches Nos. I to V were not noted for these tests which will be referred to as batches Nos. VI and VII. Excellent quantitative agreement is indicated except for the cube strengths which are much above those obtained in the main tests both at 7 and at 28 days. It seems possible that the cubes were puddled into the molds more thoroughly than were the other specimens. At least, no other explanation is apparent.

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[1] The mortar will, other things being equal, have a strength not only equal to but in excess of that of its concrete. See paper by H. J. Gilkey, "Coarse Aggregate in Concrete as a Field for Needed Research," *Proceedings*, Am. Concrete Inst., Vol. XXIII, pp. 376, 377 (1927).

Except for the cubes, the extreme ranges for slump, unit weights, and strengths at both 7 and 28 days fell within those for batches Nos. I to V. It seems reasonable to conclude that different operators can attain good agreement even though the technique is strange and their laboratory backgrounds differ widely. Batches Nos. VI and VII are treated more fully in the paper on the statistical analysis of these results.[1]

RESULTS OBTAINED AND DISCUSSION OF THE DATA

1. There developed no inherent or fundamental objections to the use of the multiple-specimen batch. The precautions and control features that were introduced seem to have accomplished the results desired of them. No lack of uniformity from either imperfect mixing or from segregation is in evidence from slumps, unit weights or strengths obtained. Standard deviations for the strengths of similar specimens both within a batch and between batches fall well within values that can be expected for well-controlled laboratory work in the field of portland-cement mixtures.

TABLE VIII.—RESULTS FROM HEAPING. MEAN 28-DAY UNIT WEIGHTS FOR EACH TYPE OF SPECIMEN.

Description	Batch Number and Casting Method										Weighted Averages		
	No. I		No. II		No. III		No. IV		No. V				
	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]	A and B[a,b]
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
Cubes, lb. per cu. ft.	143.0	144.0	142.1	145.5	142.6	144.3	141.6	.....	142.4	142.4	142.1	144.0	143.0
Prisms, lb. per cu. ft.	145.2	145.6	146.4	147.6	146.8	145.8	144.9	.....	146.0	144.5	145.9	145.9	145.9
Cylinders, 2 by 4-in.	141.5	141.7	143.3	144.6	142.8	143.0	142.9	143.0	141.9	142.5	142.8	143.0	142.9
Cylinders, 3 by 6-in.	141.7	142.3	143.3	143.4	143.0	143.4	142.9	.....	142.0	142.4	143.2	142.9	143.0
Cylinders, 6 by 12-in.	141.7	142.4	143.7	144.8	143.2	143.7	.....	.....	141.7	.....	142.2	143.9	143.0
Briquets (weight, g.)	148.2	148.6	146.6	150.5	148.7	148.3	149.0	.....	146.1	146.6	147.9	148.2	148.0
Weighted averages (except briquets)	143.0	143.9	143.8	145.9	144.5	144.2	143.1	143.0	143.2	143.1	143.8	144.1	143.9

NOTES.—All specimens saturated. Unit weights computed on basis of nominal mold dimensions. All molds of a kind were very uniform in size and dimensions which were close to the nominal. Comparative weights of specimens of a kind are more nearly valid than between different types of specimens. The close agreements indicate little probable variation in either mold dimensions or in the true unit weights.

[a] Finished flush in usual manner.

[b] Heaped and struck off flush within 3 hr. after casting. (See Table I, Line 9.)

2. The plotted 28-day 3 by 6-in. cylinder and tensile briquet control specimens (see Fig. 4) which were molded at intervals during each casting period indicate no discernible tendency toward variations in weight or strength with the time elapsed between mixing and placing up to the time of initial set which for the materials and conditions of these tests was about 4 hr. In no case did the casting period for regular specimens exceed 2.6 hr. Unplotted control cubes tested at both 7 and 28 days and briquets tested at 7 days gave like indications. The evidence from slumps and from the unit weights of both the plastic and the hardened material support the indications from strengths of the control specimens.

3. For the conditions of these tests (indoors, still air and material not spread out unduly) the reduction in water-cement ratio from evaporation was found to be inconsequential for periods which were in excess of that required for casting.

4. There were practically no differences between the batches as judged from slumps and unit weights of either the plastic or the hardened concrete, but there were consistent differences in the relative strengths as shown in Table IV. The order of

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[1] H. W. Leavitt, H. J. Gilkey and W. M. Dunagan, "Analysis of Data on Comparisons of Three Types of Mortar Compression Specimens," not yet published.

batch strengths was II, V, III, IV, I, with batches Nos. V and III nearly identical and IV and I almost the same. Batch No. II stands out as considerably stronger than any of the others. This difference might or might not have been due in part to the difference in mixing technique which was detailed early in the paper. The relative weakness of batch No. I is hardly attributable to its difference in mixing, however, since batch No. IV is very similar to No. I but was mixed exactly as were Nos. III and V.

5. The strengths of batches range (Table IV) from 95 to 108 per cent of the average batch strengths at 28 days and from 96 to 105 per cent at 7 days. The average percentage deviations are 3.8 and 2.7, respectively.

6. The average percentage standard deviations (coefficients of variation) within the different batches (Table VII) range from 4.5 to 7.9 at 28 days and from 4.7 to 7.1 and 7 days with average values of 5.6 and 5.8, respectively.

7. When all specimens of a kind, regardless of batch boundaries, are considered (Table III, columns 10 and 11), it is apparent that the deviations for the prisms are somewhat above those for any other type of specimen (except for the briquets at 28 days). This, coupled with the fact that within batches (Table VII) the standard deviations for the prisms are below those for the cubes, indicates that the different batch averages for the prisms had a greater spread than did those for the cubes. Table III shows this with a range of batch averages for the cubes of 5930 to 6640 at 28 days and averages for the prisms from 5570 to 6880. No reason for this is apparent and the question may appropriately be raised whether this relatively high standard deviation for the prisms should be accepted as significant or merely accidental. The authors are inclined to place the greater emphasis upon the evidence of high uniformity within batches. The answer then to the question of relative uniformity of results from the three different forms of test specimen cannot be given fully from the results of these tests. It may be stated, however, that none of the three types of compression specimens had standard deviations which were abnormally high.

8. As a measure of batch excellence the briquet displays little discrimination. The differences between batches are much less apparent than when results from compression tests are compared.

TABLE IX.—SUMMARY OF RESULTS AND COMPARISON OF SIMILAR SPECIMENS FROM ALL TESTS.

Description	Test Age, days	Cast On	Number of Tests	Mean Strength, lb. per sq. in.	Standard Deviation[a]		Mean Strength as percentage of			
					Lb. per sq. in.	Per cent	Cube	Prism	Cylinder, 2 by 4-in.	Specimen, Same Kind
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Cube	28	side	240	6260	454	7.2	100.0	103.1	117.0	100.0
Cube capped	28	end	28	5700	426	7.5	91.1	93.9	106.3	91.1
Cube	7	side	30	2980	82	2.8	100.0	104.2	112.5	100.0
Cube capped	7	side	4	3000	215	7.2	100.7	104.9	113.2	100.7
Cube capped	7	end	8	2600	274	10.5	87.2	90.9	98.2	87.2
Prism	28	side	178	6070	610	10.0	97.0	100.0	113.8	100.0
Prism	7	side	18	2860	296	13.5	96.0	100.0	108.0	100.0
Cylinder, 2 by 4-in.	28	end	96	5350	427	8.0	85.5	88.1	100.0	100.0
Cylinder, 3 by 6-in.	28	end	61	5520	302	5.5	88.2	90.9	103.3	103.3
Cylinder, 6 by 12-in.	28	end	7	5400	307	5.7	86.3	89.0	101.0	101.0
Cylinder, 2 by 4-in.	7	end	14	2650	192	7.2	88.9	92.1	100.0	100.0
Cylinder, 3 by 6-in.	7	end	11	2800	167	6.0	93.9	97.9	105.8	105.8
Briquet	28	side	100	470	67	14.3	7.5	7.7	8.8	100.0
Briquet	7	side	62	330	29	8.8	11.1	11.5	12.4	100.0

[a] Standard deviations for all specimens of a kind regardless of batches.

9. For these tests at 28 days the relative cube, prism and cylinder strengths are 1.03, 1.00 and 0.88. At 7 days they are 1.04, 1.00 and 0.92. The ratios of 2 by 4-in. cylinders to cube strengths are 0.855 and 0.889 respectively for the 28 and 7-day tests which are in reasonable agreement with the usually accepted ratio of 0.85 (see Table IX, columns 8 and 10).

10. As media for rating the relative excellence of batches, the cubes, cylinders and prisms all agreed closely with the mean rating of II, V, III, IV, I, for order of strengths both at 28 and at 7 days. The prisms and 2 by 4-in. cylinders agreed exactly with the mean rating at 28 days and the prisms were also in the best agreement at 7 days. The indications are such that any of these three types of specimen can be considered satisfactory as a quality measure.

11. All three sizes of cylinders agreed closely with one another in strength. The 2 by 4-in. cylinders were slightly below the other two sizes at both test ages. Relative strengths are 1.00, 1.03 and 1.01 at 28 days for 2 by 4-in., 3 by 6-in. and 6 by 12-in. specimens, respectively. There were 7-day tests on 3 by 6-in. cylinders for two batches only and no 7-day tests of 6 by 12-in. cylinders (Table IX).

12. Cubes capped and tested vertically as cast had only 0.91 and 0.87 of the 28-day and 7-day strengths, respectively, of the cubes which were tested on their sides as cast. (See Table IX, columns 8 and 11.) This apparent weakness was a surprise but is probably a correct indication. The friction developed by a spherical bearing block at relatively low loads prevents it from tilting after a test is under way. Bending, due to eccentricity of resistance (from lack of lateral homogeneity of a side-tested specimen) can be developed only as the block is able to tilt as the more flexible side of the specimen yields. On the other hand, for the vertically tested specimen, the weakest cross-section (the top as cast) occupies the entire area. Thus, the strength of the side-tested specimen is the average strength of the material from top to bottom whereas the strength of the vertically tested specimen is the strength of its weakest layer, presumably the top as cast. This explanation receives added support from the fact that prisms are stronger than the cylinders. The heights are the same and the corners of the prism certainly cannot strengthen it in comparison with the favorable circular cross-section of the cylinder. The sole pertinent difference seems to lie in the orientation at test in relation to that as cast. Comparative tests with crossed knife edges instead of a spherical bearing block should produce the necessary evidence to check the validity of the explanation offered, since knife edges could adjust themselves at all stages of the test. Such additional tests should be made.

13. The effect of a thin cement cap on the strength of a side-tested specimen (cap on side as tested, top as cast) is apparently negligible (Table IX). This is as would be expected.

14. Heaping alternate molds and striking off the excess material from one to three hours after casting apparently had no effect whatever on the average strengths developed by any type of specimen. It was suspected that such might act as a sprue to absorb the effect of water-gain, leaving the material below the sprue more homogeneous. The negative evidence obtained seems to be definite and conclusive.

15. The unreported supplementary tests (termed batches Nos. VI and VII) in which a portion of the program was duplicated by an operator who had an entirely different laboratory background gave extreme ranges for slumps, unit weights and strengths for prisms, 2 by 4-in. cylinders, 3 by 6-in. cylinders and briquets that fell entirely within those obtained for batches Nos. I to V.[1] The 28-day tests included

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[1] An unexplained discrepancy is the fact that sixty-three 28-day tests and a number of 7-day tests on cubes cast from the same batches gave strengths that were abnormally high and quite out of line with the other tests of both operators. It seems probable that unconsciously the cubes may have been puddled unduly with a corresponding extraction of water from the mixture and a lowering of the true water-cement ratio.

sixty-two 2 by 2 by 4-in. prisms, twenty-three 2 by 4-in. cylinders, nineteen 3 by 6-in. cylinders and 18 briquets. There were also a number of each type of specimen which were tested at 7 days.

This additional evidence seems to demonstrate the possibility of duplicating results within a narrow margin for these several types of specimens.

CONCLUSIONS

For the conditions of these tests the following conclusions can be offered:

1. The prism is an entirely feasible substitute for either the cube or the cylinder.
2. The strength of the prism was only slightly less than that of the cube which makes it from 10 to 15 per cent higher than that of the cylinder.
3. Contrary to expectations, cubes capped and tested vertically as cast were not stronger than companion specimens tested on their side. For these tests, the vertically tested cubes had strengths of 87 and 91 per cent at 7 and 28 days respectively. Tentative explanations have been offered.
4. The heaping or overpouring of specimens with a subsequent striking off before final hardening as a possible means of eliminating water-gain gave purely negative results. Apparently the manipulation had no consistent effect upon the strength of any of the several types of specimens.
5. Used with reasonable control measures and precautions against segregation, the multiple-specimen batch offers a satisfactory method for fabricating large numbers of duplicate or similar specimens, with a considerable reduction in total time and labor involved.
6. Were the prism to be adopted as the standard compression specimen, the datum of reference for compressive strength would be elevated from that of the cylinder to virtually that of the cube. Tests from prisms, cubes, and prisms tested as modified cubes should supply equal strengths. Where flexural tests are used, separate compressive specimens would not be required in order to obtain compression data.
7. The prism seems to be fully as sensitive as a quality measure as is either the cylinder or the cube and its indications are in agreement with those from these two types of specimens. The briquets of these tests failed to emphasize batch differences.

Acknowledgments:

The authors express their appreciation to Mr. H. F. Gonnerman and Mr. A. G. Timms of the Portland Cement Association Laboratory of Chicago for the loan of the 51 cube molds. They also wish to acknowledge the active help and cooperation of Prof. Glenn Murphy, Mr. George Ernst and Prof. W. M. Dunagan in the conduct of the tests.

APPENDIX II

METHODS OF TEST FOR DETERMINING VOLUME CHANGES IN CONCRETE

By Raymond E. Davis[1]

This report describes briefly various methods now in use for determining volume changes in plain concrete and states the test conditions to be considered by the committee in formulating a standard method of test.

With few exceptions,[2] investigators have determined "volume change" in terms of length change, and this practice is followed herein. Length changes are of direct use to engineers.

For most purposes, it is desired to know the volume change of *concrete* rather than that of *mortar* or *neat paste*. However, usually it is not practical to test concrete specimens of size comparable to that of structural elements; and for research purposes the tests are made either on mortar specimens or on small concrete specimens containing aggregate of smaller maximum size than that generally used in structures. As the amount of volume change depends greatly upon the size and type of specimen, such tests do not render *absolute* values; but the *comparative* values they afford are entirely satisfactory for comparisons as between cements, aggregates, mixes, or other variable factors. For a given structure, measurements to determine volume changes of standardized laboratory specimens would yield information regarding volume change analogous to that regarding strength which is provided by compression tests on standard cylinders.

Measurements of volume change are complicated (1) by the relatively large early movements occurring while the concrete is in a plastic or semi-plastic condition, and (2) by the difficulty of recognizing the point in the hardening period at which volume change becomes of practical moment, in order to make an initial measurement for reference. For determination of contraction upon drying, measurements are further complicated by the necessity for initial wet-curing (which may be merely retention in the molds for one day, or may be extended storage under moist conditions) before drying conditions can be applied. Restraint due to adhesion of the specimen to the mold, and internal stresses due to the fact that variations in temperature and moisture must progress inward from the surface are also factors.

In 1931 a survey was made of testing apparatus and testing methods employed by 19 investigators to determine volume changes.[3] The survey revealed a wide variety of concrete and mortar mixtures, sizes and shapes of specimen, kinds of mold, periods and conditions of curing, ages at first or base reading, and methods of observing length. Further study of recent work on volume change indicates an even greater variety of methods today.

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[1] Professor of Civil Engineering, In Charge of Engineering Materials Laboratory, University of California, Berkeley, Calif.

[2] Dilatometers have been used by Neville and Jones, Larmour, Dewey, and others.

[3] Unpublished report by H. F. Gonnerman to Section 8, Subcommittee B, Committee C-1 on Cement, Am. Soc. Testing Mats., May 22, 1931.

Test Conditions to Be Considered:

Volume-change tests may be made for any of the following purposes:

1. Under a specification limiting the amount of volume change for concrete for a given purpose, tests may be made to determine which of the available *cements* exhibit sufficiently low volume change to meet the requirement. In such a case, the possibility of using a standard aggregate (of stated type and grading) is suggested.

2. Under the same conditions as in (1), tests may be made to determine which of the available *aggregates* exhibit sufficiently low volume change to meet the requirement. In such a case, the possibility of using a standard cement (of stated composition and fineness) is suggested.

3. Under the same conditions as in (1), tests may be made to determine the *proportions* of the mix which will best meet the requirement, employing a selected cement and a selected aggregate. This case parallels that for compression tests covered by the Society's Standard Methods of Making Compression Tests of Concrete (C 39 – 33).

4. Acceptance tests may be made on specimens of concrete sampled from concrete being used in construction. This case parallels that for compression tests covered by the Society's Standard Method of Making and Storing Compression Test Specimens of Concrete in the Field (C 31 – 33).

5. Research tests may be made to determine the effect upon volume change of such factors as curing conditions, size of specimen, and shape of specimen. Although such tests cannot be fully standardized, the inclusion of tie-in tests according to standard methods is suggested.

Specimen:

In the 1931 survey it was found that many sizes of specimen were in use, as indicated by the following tabulation:

SPECIMEN	SIZE OF BARS	SIZE OF CYLINDERS
Neat cement	$\frac{5}{8}$ by $\frac{5}{8}$ by $7\frac{1}{2}$ in. to 5 by 7 by 24 in.	$1\frac{1}{2}$ by 10 in.
Mortar	Cross-section $\frac{5}{8}$ by $\frac{5}{8}$ in. to 6 by 6 in.; length 4 in. to 40 in.	2 by 4 in.
Concrete	3 by 3 by 40 in. to 8 by 8 by 60 in.	3 by 6 in. to 6 by 12 in.

Size.—The larger the specimen, the nearer the approach to structural conditions but the greater the difficulties of handling and testing. Further, the larger the specimen the more likelihood of internal stresses and cracking. The same limitations of size (with regard to maximum size of aggregate) should apply as in the case of compression specimens.

Shape.—The bar type of specimen is usually cast on its side, whereas cylinders are cast on end. Thus the measurements on bars are made in a direction corresponding to horizontal movements of structures, which movements are of greater interest to the engineer than vertical movements.

Other points of difference between bars and cylinders are with regard to (1) ease and uniformity of molding, and (2) relation of volume to surface area, when exposed to drying conditions.

Specimens in the form of flat plates have been employed to a limited extent. In apparatus of the dilatometer type, the shape of the specimen is immaterial.

Gage Points.—Contact gage points are preferably of corrosion-resisting metal, although glass plates have been used successfully by some investigators. Obviously the location and type of gage points will depend upon the measuring apparatus. For gage points in the ends of the specimen, investigators favor a convex gage point bearing against plane surfaces of the instrument.

For accurate sighting with optical comparators during the early stages of hardening, generally capillary glass tubes have been employed as gage points. These are considered satisfactory.

Molds.—Metal molds with watertight seams are employed almost exclusively. To reduce frictional restraint during the early period of hydration of the cement, the interior surfaces of molds are coated with oil or paraffin; some are lined with waxed paper, greased paper, or soft rubber.

Storage Conditions:

Storage conditions usually include both continuous storage under moist conditions and preliminary storage (ranging from perhaps 7 days to perhaps 28 days) under moist conditions followed by continuous storage under drying conditions, all at normal temperature (70 F.). Variations of these conditions are (1) continuous dry storage as soon as the molds can be removed safely, (2) alternations of wet and dry storage, (3) storage in sulfate solutions, and (4) storage at elevated temperatures, either (sealed) to simulate mass-concrete conditions, or (unsealed) to secure accelerated indications of the volume changes to be expected over long periods of time at normal temperatures.

Control of the relative humidity of the air during dry storage of specimens is necessary, as normal differences in atmospheric humidity result in volume changes of measurable magnitude. The relative humidity during dry storage is usually 50 per cent (at 70 F.). Consideration should be given to the possible use of a lower humidity in order to accelerate the test.

Control of the storage temperature is necessary, as this factor influences volume changes greatly. If variations occur, a record of temperatures should be kept in order that the volume changes due to causes other than temperature may be computed by applying corrections for temperature. If curing temperatures other than 70 F. are employed (as, for example, in mass-concrete curing), it is common practice to refer the measured lengths to the length at 70 F.

In order to estimate at early ages the probable volume changes occurring over long periods of time at normal temperatures, accelerated tests are desirable. Such tests could be made in the usual manner, except that storage would be at elevated temperatures. The effect of storage at temperatures above normal has been found to vary greatly with the type of cement and the period of storage, but it is believed that by further investigation suitable conditions can be established that would simulate long-time storage at 70 F. At present, it appears that a period of preliminary curing for 21 days at perhaps 100 F., followed by drying for 7 days at perhaps 125 F. would yield comparative results indicative of the long-time shrinkage at 70 F.

Age at First Reading:

Uncertainty exists as to the dividing lines between (1) mechanical settling or compaction of the fresh paste, mortar, or concrete in the mold; (2) more or less plastic readjustment of particles during the first several hours; and (3) true volume change of the hardened material which would affect the performance of a structure.

Of fourteen research projects described by Gonnerman, initial readings were taken within the first hour in five projects, at 20 hr. in three projects, at 24 hr. in five projects, and at 48 hr. in one project. Eleven investigators removed the molds at the age of 1 day, one at 2 days, one at 3 days, and one at 7 days.

It appears reasonable that the time of taking the first reading should be made dependent upon the cement, or at least upon the *type* of cement. In comparative tests involving slow-hardening and rapid-hardening cements, if the initial reading is made at a fixed age it is obvious that specimens containing the two cements are in different stages of development. A fairer basis of comparison would involve an initial reading when the specimen had attained a fixed strength, which would be considered an indication of its resistance to factors inducing volume change.

Age at Subsequent Readings:

As in the case of changes in strength, changes in volume of concrete are relatively greater at the early ages (either of curing or of exposure) than at the later ages; hence in order to define the continuous age-volume relation it is considered advisable to take readings perhaps at one-week intervals during the first month and perhaps at one-month intervals after the first month. Acceptance tests will probably set a limiting value on the volume changes at the age of 28 days, and the standard test will be completed at that age.

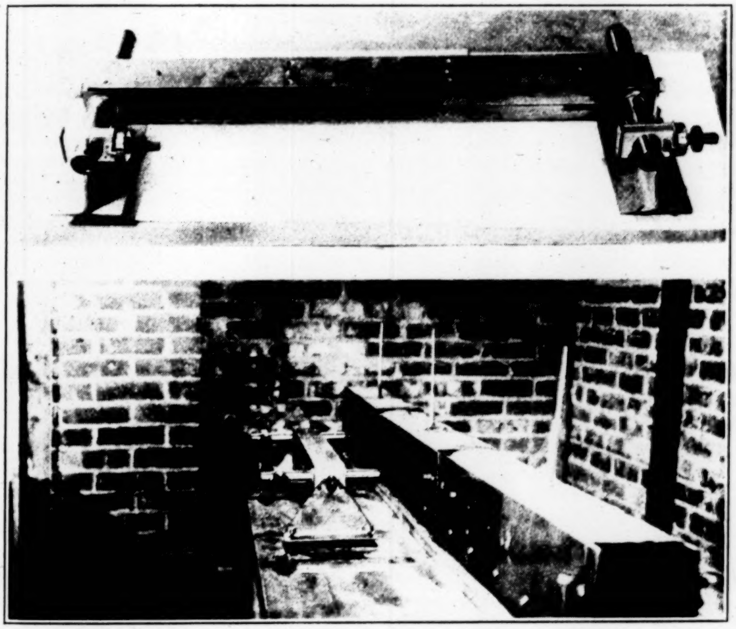


FIG. 1.—Optical Comparator Used by Richart. Specimens 4 by 4 by 24-in. bars.

Measuring Apparatus:

Apparatus for Observation During First Day.—If measurements are to be taken during the first few hours after casting, usually an optical comparator is employed, as specimens may not be handled during the early hardening stage. One type of comparator is shown in Fig. 1. Optical comparators have been used by Bogue, Davis, Faber, Gonnerman, Pearson, Richart, Scholer and Dawley, Wright and Scofield, and others.

Apparatus for Observation After First Day.—The various types of instrument commonly used for taking later readings are as follows:

1. *Strain gage,* acting against drilled or punched holes in gage plugs set in side surfaces of specimen; used by Bates, Davis, Gonnerman, Hatt and Mills,

Hughes and Levens, Maney, Richart, Shank, U. S. Bureau of Reclamation, Withey, and others.

2. *Dial micrometer* in special frame, with dial plunger acting against metal insert in one or both ends of specimen; used by Abrams, Davis, Gilkey, Gonnerman, Maney, Pearson, Richart, Slater and Lyse, U. S. Bureau of Reclamation, and others.
3. *Screw micrometer*, bearing against neat-cement caps on ends of specimen, against metal or glass inserts in ends of specimen, or against metal inserts extending from sides of specimen; used by Bogue, Goldbeck and Jackson, Miller, Moore, Thorvaldson, White, and others. One type of screw micrometer is shown in Fig. 2.
4. *Optical comparator*, the same instrument as used for readings at early ages; used by Pearson, Scholer and Dawley, Wright and Schofield, and others.

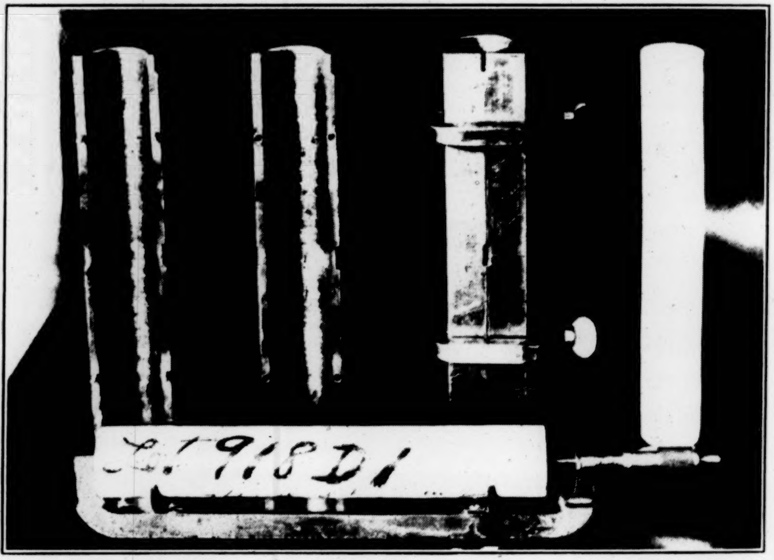


FIG. 2.—Screw Micrometer Used by Moore. Specimens $1\frac{1}{2}$ by 10-in. cylinders.

In addition to these types of apparatus, the following are of interest:

1. The *rotating mirror extensometer* employed by Glanville and by Faber. Glanville also uses this type of apparatus in his tube extensometer.
2. The *Peters telemeter*, embedded in a specimen or structure, and indicating deformation by a change in electrical resistance of a carbon pile; used by Gemeny and McCullough, Slater, National Bureau of Standards, and others.
3. The *Carlson strain meter*, embedded in a specimen or structure, and indicating deformation by a change in electrical resistance-ratio of a pair of opposed coils of steel wire; used by Stanton, U. S. Bureau of Reclamation, U. S. Engineer Corps, and others.
4. The *dilatometers* used by Neville and Jones, Larmour, Dewey, and others.

Present usage seems to favor the dial micrometer, acting against gage plugs centered in the ends of the specimen. Small specimens, weighing up to perhaps 5 lb., are measured with axis vertical (Fig. 3); larger specimens are measured with axis horizontal (Fig. 4). The apparatus shown in Fig. 4 is a diagrammatic sketch of a proposed adaptation of the author's method of measuring 3 by 3 by 40-in. bars, applied to 6 by 12-in. cylinders.

For many purposes, the use of the ordinary strain gage is advisable. The strain gage has the following advantages:

1. It is simple to operate.
2. It can be applied to specimens of a wide variety of sizes and shapes, including field test beams and actual structures.
3. If it is used on 6 by 12-in. cylinders, data on elasticity may be obtained during a compression test.

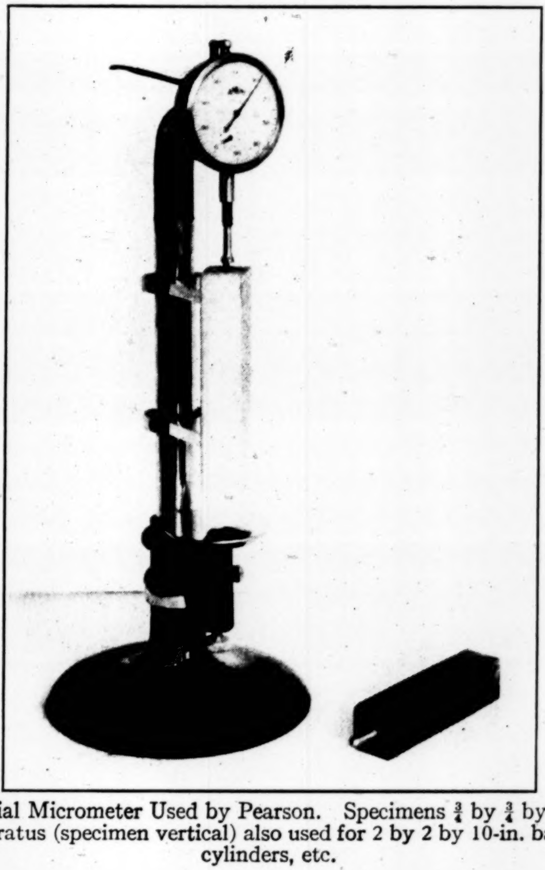


FIG. 3.—Dial Micrometer Used by Pearson. Specimens $\frac{3}{4}$ by $\frac{3}{4}$ by 4-in. bars. This type of apparatus (specimen vertical) also used for 2 by 2 by 10-in. bars and 3 by 6-in. cylinders, etc.

The chief disadvantage of the strain gage is that at least 2 gage lines are required (for cylinders, preferably 3 gage lines). Further, greater difficulty is encountered in setting the gage plugs in the sides of a test cylinder than in the ends.

Standard Bar.—Each type of apparatus should include a standard bar.

Precision.—It is believed that the purpose of most volume-change tests will be served if linear measurements are made to a least reading of 1 or 2 millionths per unit. Usually it will be sufficient to report results to the nearest 10 millionths.

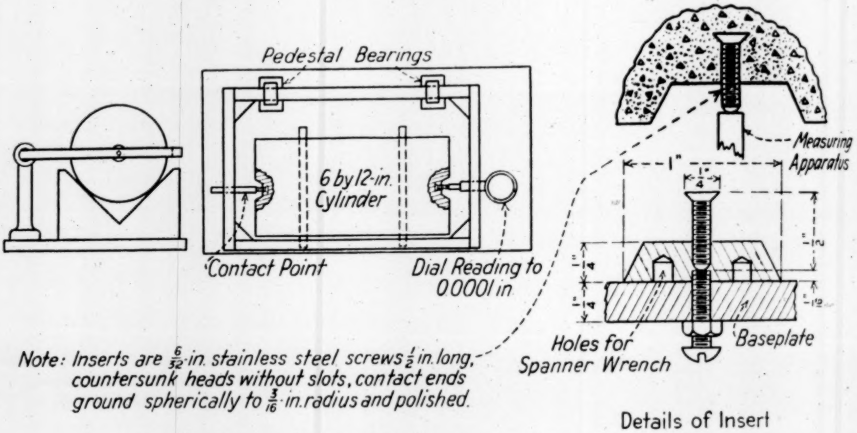
Reporting Data:

It is believed that the simplest units for the expression of volume changes are "millionths per unit of length" or, when it is understood that length changes are involved rather than volume changes, simply "millionths." This unit of measure has the advantages (1) that it is independent of the system of measuring units employed (metric or English), and (2) that for the materials and mixtures here considered the values are convenient whole numbers. Ordinarily, values would be reported to the nearest 10 millionths.

Items to be Considered in Proposed Standard Methods:

Following is a list of items to be considered by the committee in formulating proposed requirements for methods of test to determine volume changes in concrete. Obviously item 3, "Materials and Proportions," does not apply to field tests unless it is desired to make tie-in specimens with standard materials and standard mix.

1. *Specimen* (shape, size, ratio of length to diameter, gage length, gage points).



Note: Inserts are $\frac{6}{32}$-in. stainless steel screws $\frac{1}{2}$ in. long, countersunk heads without slots, contact ends ground spherically to $\frac{3}{16}$-in. radius and polished.

FIG. 4.—Proposed Dial Micrometer for 6 by 12-in. Cylinders.

2. *Molds* (substantial, watertight, size tolerance, material, base and cover plates, seams, lining, oiling, suggestions for suitable type).
3. *Materials and Proportions*
   (*cement* composition, fineness, and tests; *sand* type, grading, and tests; *coarse aggregate type*, grading, and tests; standard materials).
   (proportions of paste, mortar, or concrete).
4. *Method of Molding* (sampling, number of specimens, room conditions, preparation of materials, mixing, workability test, filling mold, compacting, setting gage points, covering, removal of mold).
5. *Curing and Storage* (period, temperature, and/or humidity (*a*) in molds, (*b*) in moist storage, (*c*) in air storage).
6. *Observations* (initial reading, subsequent readings, precision, apparatus and methods).
7. *Supplementary Tests* (unit weight, density, and yield).
8. *Report* (see the Society's Standard Methods of Making Compression Tests of Concrete C 39 – 33).[1]
9. *Alternate Tests* (accelerated, etc.).

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 230.

REPORT OF COMMITTEE C-10
ON
HOLLOW MASONRY BUILDING UNITS

Subsequent to the 1934 annual meeting, as noted in the annual report last year, Committee C-10 presented to the Society, through Committee E-10 on Standards, revisions of the specifications and methods of tests for hollow masonry building units.[1] The revised specifications and methods of tests were accepted for publication as tentative by Committee E-10 and appear in the 1934 *Proceedings*.[1]

The work of the committee since its last report to the Society has been confined to problems relating to structural clay tile. The specifications for structural clay tile have been reviewed critically to compare them with the needs of consumers. Authoritative opinions of consumers were received and considered at the meeting of the committee in Philadelphia, Pa., on March 7, 1935. Also, representatives of some of the agencies of the Federal Government gave their views at a special meeting held in Washington, D. C., on March 20, 1935. The committee has been fortunate in receiving the cooperation of both Governmental and non-Governmental agencies representing consumers. Frank statements of the views of several consumer interests have been obtained as to the possible usefulness of tile with thicker shells and also as to the possible demand for tile with shells thinner than standard. It was generally agreed that the existing information on the performance of tile in masonry does not indicate a need for specifications covering a new type of unit.

Consideration was given also to suggestions for improving the specifications. As smooth tile are usually heavier than tile with scored faces, revisions in the specified weights for smooth tiles are being proposed. The other recommended revisions are for the purpose of clarifying the intent of the specifications and to simplify their form.

RECOMMENDATIONS AFFECTING STANDARDS

Proposed Revisions of Tentative Standards:

Tentative Specifications for Structural Clay Floor Tile (*C 57 – 34 T*).[2]—The committee desires to change the form of the table of weights in these specifications to correspond with similar tables in the other specifications for tile. A few additional changes are desired also to clarify the intent of the specifications. The committee accordingly recommends that the specifications be revised as indicated below and continued as tentative:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 393; also pp. 761 to 779 (1934).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 761 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 350.

Section 1.—Change as follows by the addition of the italicized words:

1. These specifications apply to structural clay floor tile made from surface clay, shale, fire clay or admixtures thereof, *and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.*

Section 3.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

3. (*a*) Flat and segmental arch tile shall conform to the following requirements as to minimum number of cells in *depth of* arch [thickness] and average dry weights per square foot of tile:

FLAT ARCH TILE

DEPTH OF ARCH, IN.	MINIMUM NUMBER OF CELLS IN *Depth of* ARCH [THICKNESS]	AVERAGE DRY WEIGHT, LB. PER SQ. FT. OF TILE		
			Minimum	*Maximum*
6	1	[26]	*25*	*29*
7	1	[30]	*28*	*34*
8	2	[32]	*30*	*36*
9	2	[33]	*31*	*37*
10	2	[35]	*33*	*39*
11	2	[38]	*36*	*43*
12	2	[40]	*38*	*45*
13	[2] *3*	[43]	*41*	*48*
14	3	[46]	*44*	*52*
15	3	[47]	*45*	*53*
16	3	[52]	*49*	*58*
SEGMENTAL ARCH TILE				
6	2	[30]	*28*	*34*
8	2	[36]	*34*	*40*

[(*b*) A tolerance of 5 per cent under and 12.5 per cent over will be allowed on the average dry weights specified in Paragraph (*a*).]

([*c*] *b*) Tile designed to resist stresses in combination tile and concrete ribbed slab construction shall conform to the following requirements as to minimum number of cells in [thickness] *the direction of depth of slab* and average dry weights per square foot of tile:

THICKNESS OF [UNITS] *Tile*, IN.	MINIMUM NUMBER CELLS IN THICKNESS OF TILE	AVERAGE DRY WEIGHT,[a] PER SQ. FT. OF TILE		
			Minimum	*Maximum*
3	1	[15]	*13.5*	*16.5*
4	1	[16]	*14.5*	*17.5*
5	1	[19]	*17.0*	*21.0*
5	2	[23]	*20.5*	*25.5*
6	1	[22]	*20.0*	*24.0*
6	2	[25]	*22.5*	*27.5*
7	1	[24]	*21.5*	*26.5*
7	2	[27]	*24.5*	*29.5*
8	1	[27]	*24.5*	*29.5*
8	2	[29]	*26.0*	*32.0*
9	2	[31]	*28.0*	*34.0*
9	3	[36]	*32.5*	*39.5*
10	2	[33]	*29.5*	*36.5*
10	3	[38]	*34.0*	*42.0*
12	2	[40]	*36.0*	*44.0*
12	3	[45]	*40.5*	*49.5*

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[a] *The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 0.5 lb. per sq. ft. of smooth area.*

[(*d*) A tolerance of ±10 per cent will be allowed on the average weights per square foot specified in Paragraph (*c*).]

[(*e*) Structural clay floor tile units may be made any size consistent with economic considerations of manufacturing and practicable engineering standards of design.]

Section 4.—Change to read as follows by the addition of the italicized word and the omission of the word in brackets:

4. No dimension shall vary more than ±3 per cent from the [standard] *specified* dimensions for any form of tile.

Section 7.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

7. [The exterior surface] *Surfaces* of all tile intended for *the direct application of* plaster shall be scratched or scored.

Tentative Specifications for Structural Clay Non-Load-Bearing Tile (*C 56 - 34 T*).[1]—The committee recommends that the following clarifying revisions be made in these specifications and that the specifications as revised be continued as tentative:

Section 1.—Change to read as follows by the addition of the italicized words:

1. These specifications apply to structural clay partition, fireproofing and furring tile made from surface clay, shale, fire clay or admixtures thereof, *and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.*

Section 3.—Change the heading of the third column of the table of requirements from its present form: namely, "Minimum Number Cells in Wall Thickness" to read, "Minimum Number of Cells in Direction of Wall Thickness."

In the table of requirements add the following as a footnote to the columns on weights:

The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 0.5 lb. per sq. ft. of smooth area.

Section 7.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

7. [The exterior surface] *Surfaces* of all tile intended for *the direct application of* plaster or stucco shall be scratched or scored.

Tentative Specifications for Structural Clay Load-Bearing Wall Tile (*C 34 - 34 T*).[2,3]—The committee recommends that these specifications be revised as indicated below and continued as tentative:

Section 1.—Change to read as follows by the addition of the italicized words:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 765 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 354.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 768 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 357.

[3] See Editorial Note, p. 309.—ED.

1. These specifications apply to structural clay load-bearing wall tile made from surface clay, shale, fire clay or admixtures thereof, *and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.*

Section 2.—Delete Paragraph (*c*), which reads as follows, since its provisions are not enforcible:

(*c*) All tile shall be so designed that substantially the same masonry strength will be developed in all wall thicknesses for which they are to be used.

Section 3.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

3. (*a*) Load-bearing tile shall conform to the following requirements as to minimum number of cells in *the direction of* wall thickness and dry weights per square foot of tile:

In the table of requirements add the following as a footnote to the columns on weights:

The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 1 lb. per sq. ft. of smooth area.

Change the heading of the second column of the table from its present form: namely, "Minimum Number of Cells in Wall Thickness" to read "Minimum Number of Cells in Direction of Wall Thickness."

Change Paragraph (*b*) from its present form: namely,

(*b*) The weight of bonding tile, including complementary shapes, shall be governed by the requirements specified in Paragraph (*a*) and shall be calculated from the average weight of the one or more units required between header brick courses. In calculating area of tile, the greatest vertical face dimension shall be used.

to read as follows:

(*b*) The area of bonding tile shall be calculated on the basis of the average height of the two vertical faces as laid in the wall.

Change Paragraph (*d*) to read as follows by the addition of the italicized words and the omission of the word in brackets:

(*d*) Re-entrant spaces not less than 1 in. in depth and not less than 1 sq. in. in area which form cells when the units are laid [up] in the wall, shall be considered as cells in *the direction of* wall thickness, but not in the units.

Section 8.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

8. [The exterior surface] *Surfaces* of all tile intended for *the direct application of* plaster or stucco shall be scratched or scored.

Section 11.—Change the first sentence to read as follows by the addition of the italicized words:

11. Individual tile shall be rejected for failure to meet the weight, number of cells, specified size, or workmanship and finish requirements *but tiles that are overweight may be accepted at the discretion of the purchaser.*

Tentative Methods of Sampling and Testing Structural Clay Tile (*C 112 - 34 T*).[1,2]—In order to provide for uniformity and definiteness the committee recommends that the following be added as a new Section 8 and the subsequent sections renumbered accordingly:

8. *Calculating and Reporting Results.*—(*a*) The weight per unit area of a tile specimen shall be calculated by dividing the total weight in pounds by the average area of the two faces of the tile as laid in the masonry.

(*b*) The results shall be reported separately for each specimen, with the average for the five specimens.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 34 members; 24 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
REVISION OF TENTATIVE STANDARDS			
Specifications for Structural Clay Floor Tile (C 57 - 34 T)	20	1	3
Specifications for Structural Clay Non-Load-Bearing Tile (C 56 - 34 T)	23	0	1
Specifications for Structural Clay Load-Bearing Wall Tile (C 34 - 34 T)	21	1	2
Methods of Sampling and Testing Structural Clay Tile (C 112 - 34 T)	23	0	1

This report has been submitted to letter ballot of the committee, which consists of 34 members; 23 members returned their ballots, of whom 22 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

D. E. PARSONS,
Chairman.

F. E. EMERY,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 776 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 365.

[2] See Editorial Note, below.—ED.

EDITORIAL NOTE

Subsequent to the annual meeting Committee C-10 on Hollow Masonry Building Units presented to the Society on August 22, 1935, through Committee E-10 on Standards proposed revisions of the Tentative Specifications for Structural Clay Load-Bearing Wall Tile and of the Tentative Methods of Sampling and Testing Structural Clay Tile. These revisions were accepted by Committee E-10 and the tentative standards in their revised form appear on pp. 803 and 807, respectively.

REPORT OF COMMITTEE C-13
ON
CONCRETE PIPE

Committee C-13 on Concrete Pipe has held one meeting during the year, in Washington, D. C., on April 16, 1935. At this meeting certain changes in the specifications under the jurisdiction of the committee were considered.

Recommendations Affecting Standards

I. Proposed Tentative Standard:

Proposed Tentative Specifications for Concrete Irrigation Pipe.—These specifications were prepared by Subcommittee II on Reinforced Concrete Culvert Pipe (E. F. Kelley, chairman) and are being submitted for publication as tentative, as appended hereto.[1] The specifications were prepared by a group of experienced manufacturers of concrete irrigation pipe and approved by the committee at its last meeting.

II. Revision of Tentative Standard:

Tentative Specifications for Reinforced Concrete Culvert Pipe (*C 76-30 T*).[2]—Through Subcommittee II on Reinforced Concrete Culvert Pipe (E. F. Kelley, chairman) these specifications have been revised and simplified and the committee recommends that the specifications in their revised form, as appended hereto,[3] be continued as tentative.

The Joint Concrete Culvert Pipe Committee initiated the preparation of specifications for reinforced-concrete culvert pipe in 1919 and reports were issued in 1926 and 1928. In 1930 the work of the Joint Committee was taken over by Committee C-4 on Clay and Cement-Concrete Pipe and later by Committee C-13 on Concrete Pipe.

III. Adoption of Tentative Standards as Standard:

Tentative Specifications for Non-Reinforced Concrete Sewer Pipe (*C 14-34 T*).[4]—The committee recommends that these specifications which are under the jurisdiction of Subcommittee I on Concrete Sewer Pipe (Unreinforced and Reinforced) (S. A. Greeley, chairman) be revised as follows and approved for submission to letter ballot of the Society for adoption as standard. The specifications when adopted will supersede the present

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[1] See p. 812.—Ed.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 1051 (1930); also 1934 Book of A.S.T.M. Tentative Standards, p. 439.

[3] See p. 817.—Ed.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 809 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 415.

Standard Specifications for Cement-Concrete Sewer Pipe (C 14 – 24),[1] the withdrawal of which is also recommended. The changes made are based on factors developed in current use as well as manufacture of concrete sewer pipe.

Title.—Change the title of the specifications to read as follows by the omission of the word in brackets:

> Specifications for [Non-Reinforced] Concrete Sewer Pipe

Section 4.—Omit this section which reads as follows:

> 4. The purchaser may prescribe in advance special chemical requirements in cases where sewage, industrial wastes or ground waters have marked acid or alkaline character, or are of abnormally high temperatures. The purchaser may make use of chemical analysis of the pipe materials to ascertain whether these special requirements are met. The presence of deleterious materials causing slaking or disintegration shall be cause for rejection.

Section 9.—Change the first sentence to read as follows by the omission of the words in brackets:

> 9. [At the option of the purchaser] Pipe shall be tested for crushing strength by either the three-edge-bearing method or by the sand-bearing method.

Tentative Specifications for Reinforced-Concrete Sewer Pipe (C 75 – 34 T).[2] —Through Subcommittee I the committee has also prepared several changes in these specifications. The changes made are based on factors developed in current use as well as manufacture of reinforced-concrete sewer pipe. It is recommended that the specifications be revised as follows and approved for reference to letter ballot of the Society for adoption as standard:

Section 2.—Change to read as follows by the omission of the words in brackets:

> 2. Pipe, under these specifications, shall be [of two classes] known [respectively] as "Standard Reinforced-Concrete Sewer Pipe" [and "Extra-Strength Reinforced-Concrete Sewer Pipe"].

Section 3.—Change to read as follows by the addition of the italicized words and figures:

> 3. Acceptability of pipe shall be determined by the results of the strength *and absorption* tests specified in Sections 16 to 21 *and 24,* inclusive, if and when required, and by inspection to determine whether the pipe conforms to the specifications as to design and freedom from defects.

Section 4.—Change to read as follows by the omission of the words in brackets:

> 4. The reinforced concrete shall consist of portland cement, mineral aggregate and water in which steel has been embedded in such a manner that the steel and the concrete act together [in resisting forces].

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 207.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 822 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 428.

Table I.—Omit footnote *b* which reads as follows, relettering the present footnote *c* as *b:*

The steel areas in this table are based on the use of cold-drawn steel wire with a value for f_s of 27,500 lb. per sq. in. If reinforcing bars of billet steel of intermediate or hard grade are used the areas of steel given in this table shall be increased 37.5 per cent to conform to a value for f_s of 20,000 lb. per sq. in. and if billet steel of structural grade is used the areas of steel given shall be increased 53 per cent to conform to a value for f_s of 18,000 lb. per sq. in.

Table II.—Omit this table which covers the strength test requirements and minimum design requirements of extra-strength reinforced-concrete sewer pipe.

Section 14.—Change from its present form to read as follows:

14. *Strength Requirements.*—The ultimate load, as determined by either of the methods described in Section 20, shall be not less than the ultimate load specified in Table I. When the test load reaches the cracking load given in the table for the size and class of pipe tested, there shall be in the barrel of the pipe no crack having a width of 0.01 in. or more for a length of 1 ft. or more. The crack shall be considered 0.01 in. in width when the point of the measuring gage will penetrate it $\frac{1}{16}$ in. at close intervals throughout the specified distance of 1 ft. The width of crack shall be measured by means of a gage made from a leaf 0.01 in. in thickness (as in a set of standard machinist's gages), ground to a point $\frac{1}{16}$ in. in width, with corners rounded, and a taper of $\frac{1}{4}$ in. per foot, as illustrated in Fig. 1. The ultimate load is reached when the pipe shall sustain no greater load.

Absorption Requirement.—Add the following paragraph with reference to the absorption test as a new Section 16, renumbering the present sections accordingly:

16. *Test Requirements and Acceptability Under Absorption Tests.*—The absorption, determined as specified in Section 24, shall not exceed 8 per cent of the dry weight. Pipe shall be considered as conforming to these specifications for absorption when not less than 80 per cent of the number of specimens tested, including any retested, conform to the test requirements. When the initial absorption specimen from a pipe fails to conform to these specifications, the absorption test shall be made on another specimen from the same pipe and the results of the retest shall be substituted for the original test results.

Absorption Test.—Add as Sections 23 and 24 an absorption test identical to that appearing in the Tentative Specifications for Reinforced Concrete Culvert Pipe (C 76 – 30 T), renumbering the remaining sections accordingly. The method to be added is identical with the procedure for the absorption test as covered in the revised Tentative Specifications C 76, appended hereto.[1]

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 21 members; 21 members returned their ballots, the results being as follows:

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[1] See p. 826.—ED.

Items	Affirm-ative	Neg-ative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Specifications for Concrete Irrigation Pipe	17	0	4
II. REVISION OF TENTATIVE STANDARD			
Specifications for Reinforced-Concrete Culvert Pipe (C 76 - 30 T)[a]	17	4	0
III. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Non-Reinforced Concrete Sewer Pipe (C 14 - 34 T), as revised	20	1	0
Specifications for Reinforced-Concrete Sewer Pipe (C 75 - 34 T), as revised	21	0	0

[a] The classified vote on the revision of Tentative Specifications for Reinforced-Concrete Culvert Pipe was as follows: Affirmative: 6 producers, 9 consumers, 2 general interests; negative: 2 producers, 2 consumers, 0 general interests.

Respectfully submitted on behalf of the committee,

A. E. PHILLIPS,
Chairman.

M. W. LOVING,
Secretary.

REPORT OF COMMITTEE D-1

ON

PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS

Committee D-1 on Preservative Coatings for Structural Materials held a meeting on April 22, 1935, at Hotel Governor Clinton, New York City, in conjunction with the meeting of the Paint and Varnish Division of the American Chemical Society. Subcommittee meetings were held prior to the meeting of the main committee, both in New York City and previously in Philadelphia on March 5 and 6, 1935, at the time of the spring group meetings of A.S.T.M. committees.

A Symposium on Paint and Paint Materials, consisting of fifteen papers, and sponsored by Committee D-1 was held at the Regional Meeting of the Society in Philadelphia on March 6, 1935.

A number of the subcommittees have been extremely active during the past year, with the result that complete reports in considerable detail were presented by them to the committee.

Since the last annual meeting, 18 new members have been elected, 8 resignations have been accepted and 1 death reported, leaving a total membership of 182.

The work of the active subcommittees during the past year has resulted in the committee making the following recommendations to be acted upon at the annual meeting:

I. Two new tentative specifications and two tentative methods of test are being submitted;

II. Revisions are proposed for immediate adoption in two standard specifications, and as tentative in one standard specification and two standard methods of test;

III. Revisions are proposed in three tentative methods of test;

IV. Three tentative specifications are recommended for adoption as standard without revision;

V. Tentative revisions of three existing standard specifications are recommended for adoption as standard.

RECOMMENDATIONS AFFECTING STANDARDS

In this report, recommendations affecting standards and tentative standards are noted in brief form below, together with the results of the letter ballot. These recommendations are explained in the reports of the subcommittees directly responsible for them.

I. Proposed Tentative Standards.—The committee submits for publication as tentative the following two new specifications and two methods of test, as appended hereto:[1]

Tentative Specifications for White Pine Wood to be Used in Weather Tests of Paints, as proposed by Subcommittee VII;

Tentative Specifications for Blue Lead; Basic Sulfate, as proposed by Subcommittee XV;

Tentative Method of Test for Comparative Hiding Power of White Pigments, as proposed by Subcommittee VIII, and

Tentative Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number), as proposed by Subcommittee IX.

II. Proposed Revisions of Existing Standards.—The committee recommends that the revisions proposed in the following standard specifications and methods of test be accepted for publication as tentative:

Standard Specifications for Raw Tung Oil (D 12 - 33), as proposed by Subcommittee III;

Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 - 27), as proposed by Subcommittee VIII, and

Standard Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29), as proposed by Subcommittee VIII.

The committee further recommends for immediate adoption as standard, revisions in both the Standard Specifications for Dry Bleached Shellac (D 207 - 33) and the Standard Specifications for Shellac Varnish (D 359 - 34), as proposed by Subcommittee XIII. The committee accordingly asks for the necessary nine-tenths vote at the annual meeting, in order that these revisions may be submitted to letter ballot of the Society for immediate adoption.

III. Revisions of Tentative Standards.—The committee recommends that the following tentative methods of test be revised as given in detail in the report of the respective subcommittees and continued as tentative:

Tentative Method of Test for Tinting Strength of White Pigments or White Pigment Pastes (D 332 - 34 T), as proposed by Subcommittee VIII;

Tentative Methods of Test for Mass Color and Tinting Strength of Dry Color Pigments or Pastes (D 387 - 34 T), as proposed by Subcommittee VIII, and

Tentative Methods of Test for Soluble Nitrocellulose Base Solutions (D 365 - 33 T), as proposed by Subcommittee XXV.

IV. Adoption of Tentative Standards as Standard.—The committee recommends that the following tentative specifications be adopted as standard without revision:

Tentative Specifications for Titanium Barium Pigment (D 382 - 34 T), as proposed by Subcommittee XV;

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[1] See pp. 895, 873, 874 and 887.—ED.

Tentative Specifications for Titanium Calcium Pigment (D 383 - 34 T), as proposed by Subcommittee XV,

Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (95 to 96 per cent Grade) (D 343 - 32 T), as proposed by Subcommittee XXV,

Tentative Specifications for Ethylene Glycol Mono Butyl Ether (D 330 - 32 T), as proposed by Subcommittee XXV, and

Tentative Specifications for Ethylene Glycol Mono Ethyl Ether (D 331 - 32 T), as proposed by Subcommittee XXV.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Specifications for White Pine Wood to be Used in Weather Tests of Paints	55	0	16
Specifications for Blue Lead; Basic Sulfate	46	0	25
Method of Test for Comparative Hiding Power of White Pigments	47	3	21
Methods of Testing Oleo-Resinous Varnishes:			
Test for Skinning of Varnish in Closed Containers	47	0	24
Test for Alkali Resistance	47	0	24
Test for Determining Acid Number	47	0	24
II. PROPOSED REVISIONS OF EXISTING STANDARDS			
Specifications for Dry Bleached Shellac (D 207 - 33), immediate adoption	38	0	33
Specifications for Shellac Varnish (D 359 - 34), immediate adoption	38	0	33
Specifications for Raw Tung Oil (D 12 - 33)	42	0	29
Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 - 27)	50	0	21
Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29)	49	0	22
III. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Method of Test for Tinting Strength of White Pigments or White Pigment Pastes (D 332 - 34 T)	53	1	17
Methods of Test for Mass Color and Tinting Strength of Dry Color Pigments or Pastes (D 387 - 34 T)	53	1	17
Methods of Test for Soluble Nitrocellulose Base Solutions (D 365 - 33 T)	43	0	28
IV. ADOPTION OF TENTATIVE STANDARDS AS STANDARD			
Specifications for Titanium Barium Pigment (D 382 - 34 T)	52	1	18
Specifications for Titanium Calcium Pigment (D 383 - 34 T)	52	0	19
Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (95 to 96 per cent Grade) (D 343 - 32 T)	36	0	35
Specifications for Ethylene Glycol Mono Butyl Ether (D 330 - 32 T)[a]	46	0	22
Specifications for Ethylene Glycol Mono Ethyl Ether (D 331 - 32 T)[a]	46	0	22
V. ADOPTION AS STANDARD OF TENTATIVE REVISIONS OF EXISTING STANDARDS			
Standard Methods of Routine Analysis of Dry Red Lead (D 49 - 33)	50	0	21
Standard Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29)	53	0	18
Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 - 27)	52	0	19
VI. WITHDRAWAL OF TENTATIVE STANDARD			
Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (90 to 91 per cent Grade) (D 342 - 32 T)[a]	42	0	26

[a] These recommendations were submitted to letter ballot subsequent to the annual meeting, see Summary of Proceedings, p. 8.

V. Adoption as Standard of Tentative Revisions of Existing Standards.—The committee recommends that the tentative revisions submitted in 1932[1] and 1934,[2] as proposed in the following existing standards, be adopted as standard:

Revision of Standard Methods of Routine Analysis of Dry Red Lead (D 49 - 33), as proposed by Subcommittee VIII;

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 1010 (1932); also 1932 Book of A.S.T.M. Tentative Standards, p. 1154.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1265, (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1193.

Revision of Standard Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29), as proposed by Subcommittee VIII, and

Revision of Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 - 27), as proposed by Subcommittee VIII.

VI. Withdrawal of Tentative Standard.—The committee recommends that the Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (90 to 91 per cent Grade) (D 342 - 32 T) be discontinued.

The above recommendations have been submitted to letter ballot of the committee, which consists of 182 members; 71 members have returned their ballots. The analysis of the vote of the committee is given in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee III on Testing of Paint Vehicles (H. A. Gardner, chairman).—This subcommittee has prepared a tentative revision of the Standard Specifications for Raw Tung Oil (D 12 - 33). The proposed changes which appear in Appendix I[1] involve the requirements for specific gravity of tung oil and modifications in the heating test and quality test. Attention is called to the description of the thermometer for use in the heating test. The assistance of Committee D-15 on Thermometers and Laboratory Glassware has been requested for this item, but it is not likely that action can be completed in time to incorporate in the methods this year the recommendations of Committee D-15. It is therefore suggested that the paragraph as written is satisfactory and any new recommendations can be incorporated next year.

This subcommittee also recommends that the Tentative Specifications for Raw Soybean Oil (D 124 - 33 T) be retained for another year in a tentative status.

Subcommittee VII on Accelerated Tests for Protective Coatings (H. A. Nelson, chairman).—This subcommittee recommends for publication as tentative the proposed Specifications for White Pine Wood to be Used in Weather Tests of Paints, as appended hereto.[2] The grain structure and density of any species of wood are known to have great influence on the weathering of paints. It is the purpose of these specifications to minimize such variables in paint weather testing and to designate a wood which affords a practical surface for determining durability factors of exterior oil paints, and other materials of similar purpose and designed to be used for exterior exposure tests, either on vertical or 45-deg. angle, southern exposure.

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[1] See p. 1397.—ED.

[2] See p. 895.—ED.

The 1934 report of this subcommittee stated:

> It is believed by the subcommittee that as yet there is no general accelerated test available that is equally applicable to all types of finishing materials. As a laboratory tool for proving some specific points, so-called accelerated weathering tests appear to have been of value to individual laboratories when conducted by operators having experience in testing of organic finishes.

In line with this view, the reorganization of Subcommittee VII has been continued by division into the following groups:

Group 1. House Paints
Group 2. Enamels
Group 3. Varnishes
Group 4. Lacquers
Group 5. Specifications for woods for exposure panels (laboratory and outdoor)
Group 6. Metal protective finishes

Three of these groups are active. Group 3 on Varnishes, under the chairmanship of W. R. Fuller, completed one set of cooperative tests last year. The tentative conclusions from these tests were as follows:

> Differences in opinion as to the true relative outdoor durability of some of the better varnishes, and as to the stage of weathering acceptable as an endpoint, made it impossible to draw conclusions other than that certain cycles are apparently unsatisfactory and that others show some promise and are worthy of further study.

In view of this situation, Group 3 has another cooperative test under way with the varnishes used in the first test. The machines are restricted to the type which showed most promise in the preliminary test. Special care will be exercised in charting the progress of deterioration, and simultaneous outdoor exposures will be made in several localities to serve as standards for comparison.

The experience of Group 4 on Lacquers, of which H. W. Klinger is chairman, with its first set of cooperative tests was similar to that of Group 3. This group has also planned a second set of tests.

Group 5 on Specifications for Panels, under the chairmanship of C. D. Holley, is now giving attention to specifications for woods considered difficult to paint, such as yellow pine,[1] etc.

The chairmanships of Group 1 on House Paints and Group 6 on Metal Protective Finishes have been accepted by C. H. Rose and J. C. Moore, respectively, and these groups are being organized.

Subcommittee VIII on Methods of Analysis of Paint Materials (G. F. A. Stutz, chairman).—In the report of Subcommittee VIII, appended hereto, the several recommendations mentioned earlier in this report are discussed in detail.

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[1] Subsequent to the annual meeting Committee D-1 presented to the Society through Committee E-10 on Standards specifications for southern yellow pine wood to be used in weather tests of paints, which were accepted for publication as tentative and have been included in the Tentative Specifications for Wood to be Used as Panels in Weather Tests of Paints and Varnishes, see p. 895.—ED.

Subcommittee IX on Varnish (W. T. Pearce, chairman).—Subcommittee IX has been studying tests for the evaluation of varnishes and has completed the development of procedures for testing the skinning of varnish in closed containers, and tests for alkali resistance and for determining the acid number of oleo-resinous varnishes. These three methods, as appended hereto,[1] are recommended for publication as tentative and are intended when subsequently adopted as standard to be incorporated in the Standard Methods of Testing Oleo-Resinous Varnishes (D 154 – 28).

This subcommittee believes that often the acid value serves no significant purpose in the evaluation of a varnish and does not recommend the inclusion of any requirement as to acid value in a general specification. The subcommittee believes, however, that a test for acid number should be standardized so that it may be available for those who desire to use it. This subcommittee plans to continue to study methods for determining the reactivity of varnishes.

Subcommittee XIII on Shellac (J. W. Paisley, chairman).—This subcommittee recommends for immediate adoption in the Standard Specifications for Dry Bleached Shellac (D 207 – 33)[2] and for Shellac Varnish (D 359 – 34),[3] the following minor revision:

Section 2.—In the second column of the table in both standard specifications, change the maximum ash percentage specified for refined shellac from the present requirement of "0.3 per cent" to read "0.5 per cent."

This change is recommended because a recent survey and comprehensive investigation has shown that the ash content of dry refined bleached shellac on the market at present contains from 0.4 to 0.5 per cent ash, the average being just under 0.5 per cent. As all these refined shellacs satisfy the numerous commercial requirements peculiar to the product as to working qualities, etc., as well now as formerly when the ash averaged 0.3 per cent, this change is believed to be desirable.

Subcommittee XV on Specifications for Pigments Dry and in Oil When Marketed in That Form (H. E. Smith, chairman).—This subcommittee has further considered the tentative specifications for titanium pigments and recommends the following for adoption as standard, without revision:

Tentative Specifications for Titanium Barium Pigment (D 382 – 34 T)[4]
Tentative Specifications for Titanium Calcium Pigment (D 383 – 34 T)[4]

Discussion of the Tentative Specifications for Titanium Dioxide (D 384 – 34 T) indicated that further study would be desirable before proposing that these specifications be adopted as standard.

The pigment known commercially as basic lead sulfate, blue, has been on the market for many years. It is a factor in the general supply of steel protective paints. The subcommittee, with the agreement of the manufacturers, considers that it now merits a place among the A.S.T.M. specifications for pigments.

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[1] See p. 887.—ED.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 676.

[3] 1934 Supplement to Book of A.S.T.M. Standards, p. 113.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 856, 858 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 543, 545.

This subcommittee has considered this pigment which had not been previously studied and now recommends for publication as tentative the proposed Tentative Specifications for Blue Lead; Basic Sulfate, as appended hereto.[1] The requirements of these specifications conform to those recently adopted by the Federal Specifications Board.

A demand has arisen for specifications for umber and sienna. Discussion of these two pigments has finally included yellow ocher, for which the Society has for several years had Standard Specifications for Ocher (D 85 – 27). These pigments, in contrast with some others, are dependent quite largely for their practical value on physical properties, as well as on chemical composition. A small group of specialists is making an extended study of all three pigments.

The Society has for some years had Standard Specifications for Lithopone (D 208 – 26). Last year Tentative Specifications for High Zinc Sulfide Lithopone (D 385 – 34 T) and for Zinc Sulfide (D 386 – 34 T) were issued for the first time. Meanwhile, the zinc sulfide pigment industry has been making rapid strides. It now appears desirable to make a thorough study of all these pigments not only with respect to specification requirements but also as to the definition of the material that is properly classed as lithopone, as well as the classification and definition of other pigments containing zinc sulfide. A group of specialists has been appointed for this purpose and will report next year.

Subcommittee XVIII on Physical Properties of Materials (F. P. Ingalls, chairman).—This subcommittee has held two meetings of its group interested in the definition of gloss. A study of this subject has resulted in the formulation of certain proposed definitions that, while not sufficiently specific for general acceptance, do represent the consensus of opinion of the group conducting the study. The definitions embrace the terms: "gloss," "polish" and "image reproducibility."

It was agreed that these proposed definitions should be submitted for comment to members of the various industries interested in this subject, in order to obtain some idea as to whether they are sufficiently fundamental to serve as a basis from which to approach formulation of a method of specifying that characteristic known as gloss. This subcommittee does not desire to submit these proposed definitions for publication as tentative until a study has been made of such comments as may be received.

Subcommittee XXV on Cellulose Ester Coatings (R. M. Carter, chairman).—This subcommittee recommends that the Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (95 to 96 per cent

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[1] See p. 873.—ED.

Grade) (D 343 – 32 T), for Ethylene Glycol Mono Butyl Ether (D 330 – 32 T) and for Ethylene Glycol Mono Ethyl Ether (D 331 – 32 T) be submitted to the Society for adoption as standard. The withdrawal of the Tentative Specifications for Acetate Ester of Ethylene Glycol Mono Ethyl Ether (90 to 91 per cent Grade) (D 342 – 32 T) is also recommended. It is further proposed that the five tentative specifications and one method of test for solvents and diluents under its jurisdiction be retained as tentative without revision. Three of the specifications have been tentative for three years without change. No recommendation is made for their adoption as standard at this time because of minor changes that are anticipated.

The subcommittee has developed a method for determining depth of color, which is proposed for inclusion as appended hereto[1] in the Tentative Methods of Test for Soluble Nitrocellulose Base Solutions (D 365 – 33 T). This method of color determination has been developed to meet the need for a standardized method applicable to nitrocellulose base solutions having a color that is usually darker than that of nitrocellulose lacquers. It further serves to complete the testing methods usually applied to such base solutions and completes the work along this line that was instituted by this subcommittee. It is essentially the procedure in use by many of the leading producers and consumers of heavy base solutions.

Subcommittee XXV has been cooperating with Committee D-2 on Petroleum Products and Lubricants in a revision of the Standard Method of Test for Flash Point of Volatile Flammable Liquids (D 56 – 21) so that this method will be applicable to the testing of the low-flash point lacquer solvent and diluents. A revision of the standard method is being submitted by Committee D-2 to the Society this year for publication as tentative.[2]

Subcommittee XXVI on Underground Pipe Protection (F. N. Speller, chairman).—This subcommittee is not ready to submit specifications for bituminous primary coating. The work has been delayed mainly for lack of a satisfactory test for adhesion and a method of testing the durability of these and other paint coatings, and data based on such a test. This committee suggested to the Advisory Committee of Committee D-1 last year that specifications for testing paints under submerged conditions be formulated. The Advisory Committee then requested that an outline of such a specification be prepared by this subcommittee for consideration of Committee D-1. This has been done with the cooperation of H. A. Gardner, A. M. Muckenfuss and P. H. Walker and was submitted to the Advisory Committee. At the request of the Advisory Committee this statement is made a part of this report and is published for soliciting comments and discussion:

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[1] See p. 889.—ED.
[2] See p. 897.

STATEMENT ON PRINCIPLES OF TESTING PAINTS AND COMBINATIONS OF PAINTS ON STEEL PANELS

WITH PARTICULAR REFERENCE TO SUBMERGED CONDITIONS

1. *General:*

(*a*) Records should be made of the analysis and percentages of vehicle and pigment used in the paint; also physical properties and weight per gallon of each coat.

(*b*) Separate laboratory tests of each coat and of the combined coats should be made for permeability to water.

(*c*) It is desirable to test paints for under-water use by immersion in at least two or three different kinds of water. The waters in which the tests are to be made should be analyzed and full analyses inserted in the records.

(*d*) Bare panels of the same steel should be similarly exposed. In fact it seems desirable to conduct tests of metals and protective paints under the same environment.

(*e*) Tests should be made and record kept of the spreading properties of each coat.

2. *Preparation of Surface:*

Preparation of the surface is very important in order to get comparative tests. All grease and dirt should be removed and the surface sandblasted or pickled free from scale. Sandblasting is preferable. After cleaning, the test panels should be kept in a dry room or otherwise protected to avoid rusting. Just before applying the first coat, the metal should be given another cleaning operation by sandblasting or thorough scratch brushing to remove any rust that may have formed since the panels were cleaned.

3. *Application of Paint:*

Immediately after the final cleaning, the priming coat should be brushed on and observations taken of the temperature and humidity of the air. Painting should be done indoors with a humidity less than 80 per cent. Sounder films can usually be obtained by drying outdoors in sunlight. It is important, therefore, to dry test panels under controlled conditions. The time required to dry to touch should be recorded. The actual time permitted for drying between coats depends on the type of service. For paints intended for ship bottoms, or other structures where the drying time is limited, 24 hr. between coats should be allowed. For other purposes a fixed drying time of not less than 48 hr. between coats is recommended. However, *all* paints tested for a specific purpose should be given the same drying time.

When the first coat has been given the specified drying time, a second coat should be applied in the same way with the required drying time before immersion.

The second coat should be applied from top to bottom over the first coat, but on only one-half of the panel. Edges of test panels should be further protected by dipping in a shallow pan containing a durable quick-drying paint. When the final coat is dry and just before it is put under test, a scratch should be ruled with a sharp tool across the panel about four inches from the bottom with enough pressure to penetrate the paint and slightly mark the metal.

It is recommended that No. 16-gage steel panels 8 by 12 in. be used. American hot-rolled (blue) annealed basic open-hearth steel with copper contents not exceeding 0.03 per cent is available in most of the jobbing houses and is recommended for standard panels.

4. *Adhesion:*

Test samples should be prepared at the same time the panels are painted for test under impact and by bending to determine the adhesion of the coating to the metal and any tendency to crack or spall. (Details in regard to these tests and the permeability test should be specified.)

5. *Testing Method:*

Various methods have been used for conducting panel tests. Submerged tests in water may be made by placing the panels on a hinged rack so that the whole batch can be readily lowered into the water and removed for examination. Mr. H. A. Gardner uses a tank 6 ft. long by 24 in. wide by 6 in. deep. For alternate wetting and drying the rack can be easily immersed over night and exposed to the weather and sun during the daytime. The size of the panels should not exceed 5 by 10 in. so that the rack will not be too heavy. This test gives a fairly quick indication of durability of paints under atmospheric and alternate immersion conditions.

It may be desirable in the preliminary study of paints to conduct atmospheric, partial-immersion, and total-immersion tests, at the same time and in the same locality, but atmospheric tests are apt to be misleading when made in localities where the rainfall varies widely from year to year, unless periodically sprinkled with water.

Test panels should be insulated at least 1 in. from each other and be submerged in a vertical position.

The Sub-Tropical Testing Laboratory at Miami, Fla., uses two methods of testing paints for partial and fully submerged water service. A tide water rack is securely attached to the wharf facing south and panels are placed upon this rack. At high tide the panels are completely submerged; at low tide, completely out of the water. For continuous exposure to water the panels are placed on a rack and suspended by a rope or suitable cable and weighted to prevent excessive movement.

The final test of any paint should, of course, be carried out in several localities under service conditions.

Inspection of test panels should be made at least every three months by removing and cleaning the samples, taking precautions to avoid injury to the coating. Records should be made of blistering and whether this is found under the first or under both coats. Observations should also be made as to the formation of rust tubercles, which would indicate total failure of the coating. The use of a "ferricyanide pattern test" on paint coatings, similar to the method developed by Ewing and Scott[1] at the National Bureau of Standards, might be used to indicate initial breaks and porosity in coatings. This test when applied with proper technique to new paint might indicate faulty application.

A panel painted with a standard material that is readily obtainable, such as red lead (U. S. Navy formula) should be used for comparison in all tests.

Some of the more important factors involved are outlined briefly above for comments and as a basis for the formulation of a Code of Procedure for Testing Paints.

This report has been submitted to letter ballot of the committee, which consists of 182 members; 71 members returned their ballots, of whom 34 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

M. REA PAUL,
Secretary.

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[1] G. N. Scott, "Pipe Coating Tests," *Proceedings*, Am. Petroleum Inst., 1931, and also subsequent reports.

REPORT OF SUBCOMMITTEE VIII ON METHODS OF ANALYSIS OF PAINT MATERIALS

Subcommittee VIII has adopted a program of cooperative work on hiding power with a view toward revising and improving the present method of test for hiding power of paints. Definite progress can be reported in this cooperative work, but the detailed information is not in form to be submitted at this time. It is expected that this work will permit a revision of the method next year. At the present time, this subcommittee recommends that the present Tentative Method of Test for Comparative Hiding Power of Paints (D 334 - 32 T) be continued as tentative without revision.

The Tentative Method D 334 - 32 T does not permit the determination of the hiding power of pigments. This subcommittee accordingly recommends for publication as tentative a Method of Test for Comparative Hiding Power of White Pigments, as appended hereto.[1] While the method used in this test is being studied in the present cooperative work and will possibly be somewhat modified during the next year, it is considered desirable to introduce a method of test for pigments at this time.

The subcommittee recommends that the tentative revisions proposed in 1932[2] and 1934[2] in the following standards be submitted to the Society for adoption as standard:

Revision of Standard Methods of Routine Analysis of Dry Red Lead (D 49 - 33)

Revision of Standard Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29)

Revision of Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (D 126 - 27)

Tentative Method for Tinting Strength of White Pigments or White Pigment Pastes (D 332 - 34 T).[3]—At the June, 1934, meeting Subcommittee VIII sponsored a symposium on tinting strength of dry colors and of white pigments. As a result of the data given and discussion in that symposium, this subcommittee has considered it desirable to make some rather extensive changes in its tinting strength methods. An attempt has been made to have the tinting strength procedure described in the tentative methods conform as far as possible to the method adopted by the Federation of Paint and Varnish Production Clubs. A revision of the Tentative Method D 332 - 34 T has, therefore, been prepared and incorporated in the completely modified method, appended hereto,[1] which the subcommittee recommends be accepted and the method as revised continued as tentative.

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[1] See p. 874.—Ed.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, pp. 1010 to 1014 (1932) and Vol. 34, Part I, pp. 1265 to 1271 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 1193 to 1199.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 866 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 553.

Tentative Methods of Test for Mass Color and Tinting Strength of Dry Color Pigments or Pastes (D 387 - 34 T).[2]—For the same reasons as indicated above, the subcommittee also recommends that these tentative methods be revised as follows and continued as tentative:

Section 2.—Change Paragraph (*a*) of this section to read as follows by the addition of the italicized words:

(*a*) Balance.—Regulation laboratory balance, ***sensitive to at least 1 mg.***

Add the following sentence at the end of Paragraph (*c*) of this section:

The edge should be beveled.

Section 3 (*b*).—Add the following formula, following Formula No. 2 in this section:

No. 3............................ { 100 lb. Green Seal zinc oxide
25 lb. Heat bodied oil (of "O" Litho varnish consistency)

Section 4.—Change the table, appearing in Paragraph (*a*) of this section, to read as follows by the addition of the italicized words and figures and the omission of the figure in brackets:

TOTAL NUMBER OF RUBS REQUIRED FOR PIGMENT	PICK-UP REQUIRED
300	after each 50 rubs
200	after each 40 rubs
150	***after each 30 rubs***
100	after each 25 rubs
80	***after each 20 rubs***
[50] *60*	after each 15 rubs

In Paragraph (*b*) of this section, delete the fifth sentence, which reads as follows:

Observation for floating, bronzing, etc., shall be taken note of after 2 or 3 hr., if this fact is important to the purchaser.

Add the following note at the end of Paragraph (*b*):

NOTE.—Where higher precision is required than that afforded by visual examination or where it is desirable to determine the color characteristics of the material in terms of fundamental physical units, this may be done by use of the Standard Method of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (A.S.T.M. Designation: D 307) of the American Society for Testing Materials.[3]

Section 5 (*b*).—In the table giving the pigment rub-out scheme, appearing in this section, under the column headed "Mulls or Rubs," change all figures now given as "50" to read "60" and all figures now given as "75" to read "80."

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[1] See p. 877.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 871 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 558.

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 731.

In the same table under the column headed "Reduction, Grams of Reduction Paste to Grams of Mulled Paste," change the figures for high strength carbon black, lampblack, and carbon black from "2 to 0.1" to read "5 to 0.1."

Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments, and Chrome Green (D 126 - 27).[1]—It has been pointed out that iron blue sold today is practically all soda blue instead of the potash blue formerly used. As a result, the factor now given in A.S.T.M. methods, namely, that for potash blue, is incorrect. The subcommittee accordingly recommends that the following revision of this standard method be accepted for publication as tentative:

Section 24.—Change this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 24. The percentage of Prussian blue may be obtained with sufficient accuracy for commercial purposes by multiplying the percentage of nitrogen by [4.4] *3.404* or the percentage of [iron (in the absence of other iron pigments) by 3.03] *ammonia by 2.8.*

Standard Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 29).[2]—It has been pointed out that in determining the nature of the thinner in the routine analysis of white linseed oil paints, it is difficult to determine the amount of turpentine in the thinner when it is present in only small amounts. A modification has been suggested by Mr. Floyd Roberts of the North Dakota Regulatory Department and it has been found by several laboratories to work satisfactorily. The subcommittee accordingly recommends that the following revision of this standard method be accepted for publication as tentative:

Nature of the Thinner.—Add the following paragraph at the end of this section:

> When the amount of turpentine in the thinner is small so that its presence is questionable, it may be detected by placing two drops of the distillate and 2 to 3 ml. of chloroform in a dry test tube and adding one drop of antimony pentachloride. A slow or slight change in color will indicate the absence of turpentine. A rapid change in color to a dark red or purple will indicate the possibility of turpentine. The iodine number for turpentine by the Wijs method under these conditions is approximately 340. An iodine number of 20 or over will give additional proof of the presence of turpentine and enable calculation of the approximate amount.

Respectfully submitted on behalf of the subcommittee,

G. F. A. STUTZ,
Chairman.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 617.
[2] *Ibid.*, p. 583.

REPORT OF COMMITTEE D-2

ON

PETROLEUM PRODUCTS AND LUBRICANTS

Committee D-2 on Petroleum Products and Lubricants held three regular meetings during the past year (in June at Atlantic City, N. J., in January at New York, N. Y., and in March at Philadelphia, Pa.) and also an informal meeting in November at Dallas, Tex., at the time of the annual meeting of the American Petroleum Institute.

During the year, the name of Subcommittee XXVII on Classification of Transmission Lubricants and Automotive Greases was changed to Classification of Automotive Lubricants so as to include crankcase oil.

Acting as Sectional Committee Z11 on Nomenclature and Methods of Testing Petroleum Products and Lubricants, functioning under the procedure of the American Standards Association, the following recommendations in connection with American Standards have been made during the year:

Approval of Revision of American Standards:

Method of Test for Cloud and Pour Points (D 97 – 34) (A.S.A. No. Z11.5 - 1934)
Method of Test for Sulfur in Petroleum Oils by Bomb Method (D 129 – 34) (A.S.A. No. Z11.13 – 1934)
Abridged Volume Correction Table for Petroleum Oils (D 206 – 34) (A.S.A. No. Z11.1 – 1934)

These recommendations have been approved by the American Standards Association with A.S.A. numbers as indicated.

Acting on the recommendation of Committee D-2,[1] Committee E-10 on Standards on August 22, 1934, accepted for publication the Tentative Specifications for Fuel Oils (D 396 – 34 T).[2]

The voting membership of Committee D-2 now consists of 41 producer, 33 consumer, and 13 general interest members.

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[1] In submitting these tentative specifications to Committee E-10 on Standards the committee reported the results of the letter ballot as follows: Of the voting membership of Committee D-2, consisting of 84 members, 66 members returned their ballots, of whom 48 voted affirmatively, 10 negatively and 8 marked their ballots "not voting." Of the voting membership of Technical Committee C consisting of 75 members, 45 members returned their ballots, of whom 38 voted affirmatively, 5 negatively and 2 marked their ballots "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 882 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 591.

ACTIVITIES OF SUBCOMMITTEES AND TECHNICAL COMMITTEES

Appended hereto is the report of Subcommittee X on Sligh Oxidation Test.

Subcommittee I on Corrosion Test for Lubricating Oils (H. C. Mougey, chairman) is cooperating with a subcommittee of the Lubricants Division of the Society of Automotive Engineers in the development of laboratory test methods which will correlate with road service. The present program involves the following:

1. *Laboratory Corrosion Tests* in which the bearing metal is heated in the lubricant under test at an elevated temperature for a definite period of time. (This type of test will indicate loss in weight and loss in dimensions and would serve to eliminate corrosive lubricants. Lubricants which pass this test would also have to pass the laboratory and engine tests mentioned below under items 2 and 3.)
2. *Laboratory Bearing Tests* in which bearings are operated at loads, speeds and temperatures comparable to service. (This test will determine the behavior of a specific bearing and lubricant combination, but would not necessarily determine if the combination would function satisfactorily in an engine of specific design.)
3. *Engine Tests* in which the specific combination of bearing material and lubricant is tested under actual service conditions.

The cooperation of the subcommittee is particularly with respect to items 1 and 2, as item 3 is primarily a function of the engine manufacturer.

Subcommittee XX on Nomenclature (A. E. Miller, chairman) is engaged in the preparation of a dictionary of terms used in the petroleum industry, in three languages, English, French, and German. This work is being done in collaboration with Technical Committee No. 28 on Nomenclature and Methods of Testing Petroleum Products and Lubricants of the International Standards Association.

An effort is also being made by this subcommittee to obtain more general adoption of the "ine" spelling of kerosine which has been employed for many years by the Society, The Institution of Petroleum Technologists, and a limited number of publications.

Subcommittee XXVII on Classification of Automotive Lubricants (H. C. Mougey, chairman) is cooperating with the S.A.E. Lubricants Division on a revision of the viscosity limits in the S.A.E. Crankcase-Oil Viscosity Numbers. There is also under consideration a system of designating various grades of automotive greases, which is being undertaken jointly with the S.A.E. Lubricants Division and the Committee on Standards and Specifications of the National Association of Lubricating Grease Manufacturers. Further developments on this problem await the completion of a survey by the N.A.L.G.M. of greases now being marketed.

Technical Committee C on Fuel Oils (Including Diesel Fuel) (Lee Schneitter, chairman).—On the recommendation of Section I on Domestic and Industrial Fuel Oil (H. C. Dickinson, chairman), which also functions as the standing committee on fuel oils of the Commercial Standards Group of the Department of Commerce, that the Commercial Standard for Fuel Oils (CS 12 – 33) be revised to conform to the A.S.T.M. Tentative Specifications for Fuel Oils (D 396 – 34 T), the industry has been canvassed and these specifications have been promulgated as Commercial Standard for Fuel Oils (CS 12 – 35), third edition, effective February 15, 1935. A meeting of Section I was held on January 11, 1935, to consider suggestions for further revision of the specifications for fuel oils and plans were made to obtain additional information in regard to the effects of carbon residue values and the causes of difficulties with certain cracked fuels. A request was transmitted to Subcommittee V on Viscosity to consider and recommend methods for obtaining viscosity values at 32 F.

Section II on Diesel Fuel Oils (L. H. Morrison, chairman) held a meeting on January 11, 1935, at which T. B. Rendel, chairman of the Volunteer Group for Compression-Ignition Fuel Research, presented a summary of what had been done in developing a method for determining the ignition characteristics of Diesel fuels with a modified C.F.R. engine and of its program for further work.

A revision of the Diesel-Fuel-Oil Classification which first appeared in the 1934 report of the committee is shown as Appendix II.

The joint relation with the former Special Research Committee on Diesel Fuel Specifications of the American Society of Mechanical Engineers was terminated by the disbanding of the A.S.M.E. committee.

RECOMMENDATIONS AFFECTING STANDARDS

I. *Proposed Revisions of Standards:*

The committee recommends editorial changes in one standard method, as indicated below, and also proposes modifications of five standard methods for publication as tentative revisions.

Standard Method of Test for Cloud and Pour Points (D 97 – 34).[1]— The following editorial changes to become effective immediately are recommended by Subcommittee XVI on Cloud and Pour Test (J. B. Rather, chairman) to clarify the meaning:

Section 10.—Change the last two sentences of the sixth paragraph to read as follows by the addition of the italicized words:

> If the oil does not show a cloud when it has been cooled to 50 F., the test jar shall be placed *in the jacket* in a second bath maintained at a temperature of 0 to +5 F. If the oil does not show a cloud when it has been cooled to 20 F., the test jar shall be placed *in the jacket* in a third bath maintained at a temperature of –30 to –25 F.

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 117.

Section 12.—Change the caption above this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

> Special Procedure for Black Oils [and], Cylinder Stocks *and Non-Distillate Fuel Oils*

Change Paragraph (*c*) to read as follows by the addition of the italicized word and the omission of the word in brackets:

> (*c*) *Both* the upper and lower pour points shall be reported [separately].

Standard Method of Test for Distillation of Crude Petroleum (*D 285 - 33*).—Tentative revisions, appended hereto,[1] in this method, are recommended by Subcommittee XXI on Crude Petroleum (A. J. Kraemer, chairman) to improve the accuracy and reproducibility of the method. The statement of accuracy in the naphtha distillation is not properly a part of the method and its deletion is being recommended.

Standard Method of Flash Point by Means of the Pensky-Martens Closed Tester (*D 93 - 22*).—Tentative revisions, appended hereto,[2] in this method are recommended by Subcommittee XII on Flash Point (J. B. Terry, chairman) to provide a procedure for the determination of the flash point of cut-back asphalts and other viscous materials and suspensions of solids.

Standard Method of Test for Flash Point of Volatile Flammable Liquids (*Tag Closed Tester*) (*D 56 - 21*).—Revision of this method in the form of a new tentative method, appended hereto,[3] is recommended by Subcommittee XII on Flash Point (J. B. Terry, chairman). This represents a change in form and includes additional provisions for testing lacquer solvents which originated in Committee D-1 on Preservative Coatings for Structural Materials.

Standard Method of Test for Saponification Number (*D 94 - 28*).—Tentative revisions, appended hereto,[4] in this method are recommended by Subcommittee XIII on Neutralization Number and Saponification (E. B. McConnell, chairman) to provide information respecting the limitations of the method.

Standard Method of Test for Viscosity of Petroleum Products and Lubricants (*D 88 - 33*).—Revision of this method in the form of a new tentative method appended hereto,[5] is recommended by Subcommittee V on Viscosity (J. C. Geniesse, chairman) to define more closely the procedure for determining viscosity by the Saybolt instrument.

II. Adoption of Tentative Revisions of Standards as Standard:

The committee recommends that the tentative revisions[6] proposed last year in the following standard methods be submitted to the Society for adoption as standard:

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[1] See p. 1400.—Ed. [2] See p. 1401.—Ed. [3] See p. 897.—Ed. [4] See p. 1402.—Ed. [5] See p. 914.—Ed.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1272 and 1273 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 1200 and 1201.

Revision of Standard Method of Test for Dilution of Crankcase Oils (D 322 – 33)

Revision of Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 – 30)

Revision of Standard Method of Test for Precipitation Number of Lubricating Oils (D 91 – 33)

Revision of Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 30)

III. *Tentative Standards Continued as Tentative:*

Four methods of test and the tentative definitions under the jurisdiction of the committee have been tentative for a period of three years or longer without revision, as follows:

Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants (D 188 – 27 T)

Tentative Method of Test for Expressible Oil and Moisture in Paraffin Waxes (D 308 – 29 T)

Tentative Method of Test for Vapor Pressure of Natural Gasoline (Reid Method) (D 323 – 32 T)

Tentative Standard Viscosity-Temperature Chart for Liquid Petroleum Products (D 341 – 32 T)

Tentative Definitions of Terms Relating to Petroleum (D 288 – 31 T)[1]

The second of these methods is highly empirical and it has not had a sufficiently long trial to justify its adoption because of its relatively infrequent use. The other tentative methods and the tentative definitions will probably be revised before they are recommended for adoption as standard. It is accordingly recommended that they be continued as tentative.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 87 members; 66 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED REVISIONS OF STANDARDS			
Test for Cloud and Pour Points (D 97 – 34), editorial revision	60	1	5
Test for Distillation of Crude Petroleum (D 285 – 33)	55	2	9
Test for Flash Point by Means of the Pensky-Martens Closed Tester (D 93 – 22)	58	2	6
Test for Flash Point of Volatile Flammable Liquids (Tag Closed Tester) (D 56 – 21)	58	1	7
Test for Saponification Number (D 94 – 28)	61	0	5
Test for Viscosity of Petroleum Products and Lubricants (D 88 – 33)[a]	59	1	3
II. ADOPTION OF TENTATIVE REVISION OF STANDARDS AS STANDARD			
Test for Dilution of Crankcase Oils (D 322 – 33)	61	0	5
Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 – 30)	65	0	1
Test for Precipitation Number of Lubricating Oils (D 91 – 33)	61	1	4
Test for Water and Sediment in Petroleum Products By Means of Centrifuge (D 96 – 30)	61	2	3

[a] These are the results of the letter ballot vote canvassed subsequent to the annual meeting on the method as revised, see Summary of Proceedings, p. 11.

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[1] See Editorial Note, p. 332.—ED.

This report has been submitted to letter ballot of the committee, which consists of 87 members; 66 members returned their ballots, of whom 65 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

R. P. ANDERSON,
Secretary.

T. A. BOYD,
Chairman.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-2 on Petroleum Products and Lubricants presented to the Society on August 22, 1935, through Committee E-10 on Standards the following additional recommendations:

Proposed Tentative Method of Test for Vapor Pressure of Motor and Aviation Gasoline (Reid Method) (D 417-35 T).

Revision of the Tentative Definitions of Terms Relating to Petroleum (D 288-31 T) comprising a slight modification of the definition for fuel oil.

A tentative revision of the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287-33).

The above recommendations were accepted by Committee E-10 and appear respectively on pp. 903, 920 and 1402.

REPORT OF SUBCOMMITTEE X ON SLIGH OXIDATION TEST

To obtain data on the reproducibility of the results obtainable with the Sligh oxidation test, samples of three different oils and of one A.S.T.M. precipitation naphtha[1] were sent out to a number of cooperating laboratories with requests that values of Sligh oxidation number be obtained in triplicate. The results reported by the various laboratories are shown in Table I.

The results of laboratory No. 1 are consistently low, whereas, those of laboratory No. 3 are consistently high. The data for oil No. 3 reported by laboratory No. 9 are the only ones seriously out of line and, in general, very good agreement is shown between the various laboratories. On the average, the different laboratories were found to agree within 10 per cent, whereas, check results by the same laboratory were in much closer agreement.

TABLE I.—RESULTS OF SLIGH OXIDATION TESTS REPORTED BY COOPERATING LABORATORIES.

Laboratory	Oil No. 1 Using A.S.T.M. Precipitation Naphtha			Oil No. 2 Using A.S.T.M. Precipitation Naphtha			Oil No. 3 Using A.S.T.M. Precipitation Naphtha		
	Sligh Oxidation Number	Average	Deviation from Average	Sligh Oxidation Number	Average	Deviation from Average	Sligh Oxidation Number	Average	Deviation from Average
No. 1..	7.7, 8.0, 6.3, 7.8, 5.8	7.1	1.5	25.3, 27.9, 26.7, 27.3, 26.5	26.7	3.0	44.4, 42.8, 38.2, 44.4, 40.2	42.0	4.6
No. 2..	7, 9, 11	9.0	0.4	33, 32, 29	31.3	1.6	47, 45, 45	45.7	0.9
No. 3..	8.9, 9.9, 11.8	10.2	1.6	36.7, 37.7, 35.7	36.7	7.0	51.8, 50.0, 51.7	51.2	4.6
No. 4..	7.2, 7.9, 7.9, 7.6	7.7	0.9	29.8, 28.6, 26.9, 27.6	28.2	1.5	46.5, 44.5, 45.0, 42.6, 42.3	44.2	2.4
No. 5..	5.8, 8.3, 8.5	7.5	1.1	22.8, 25.4, 26.8	25.0	4.7	45.6, 47.7, 46.3	46.5	0.1
No. 6..	7.5, 7.9, 8.1, 7.6	7.8	0.8	28.2, 28.0, 30.5, 29.2	29.0	0.7	41.6, 42.4, 38.4, 43.0	41.3	5.3
No. 7..	10, 7, 10	9.0	0.4	29, 29, 28	28.7	1.0	44, 44, 47	45.0	1.6
No. 8..	9.9, 9.1, 10.0, 8.3, 9.6	9.4	0.8	26.8, 27.7, 24.0, 24.9, 30.9, 28.6, 29.2, 29.5	27.7	2.0	44.5, 43.2, 45.0, 45.2, 40.8	43.7	2.9
No. 9..	7.3, 8.6, 9.5	8.5	0.1	34, 33, 30	32.3	2.6	57, 58, 64	59.7	13.1
No. 10..	9.3, 10.1, 10.0	9.8	1.2	30.2, 31.1, 31.5	30.9	1.2	45.9, 46.2, 47.6	46.6	0.0
Grand average		8.6±1.2			29.7±2.6			46.6±3.7	

In addition to the determinations with the A.S.T.M. precipitation naphtha, each laboratory was requested to make tests if possible on the three oils using their own precipitation naphthas. The average results of these tests are shown in Table II in comparison with the average results using the A.S.T.M. naphtha supplied for the tests. Very good agreement was found between the grand average values for the two naphthas. In taking the grand average for the laboratory naphthas, the data obtained by laboratories Nos. 5 and 9 were omitted since the naphthas used were not comparable with A.S.T.M. precipitation naphtha.

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[1] The petroleum naphtha conformed to the requirements in Section 6 of the Standard Method of Test for Precipitation Number of Lubricating Oils (A.S.T.M. Designation: D 91), see 1935 Supplement to Book of A.S.T.M. Standards, p. 186.

TABLE II.—COMPARISON OF AVERAGE RESULTS WITH A.S.T.M. PRECIPITATION NAPHTHA DISTRIBUTED AND WITH THE NAPHTHA USED BY EACH LABORATORY.

Laboratory	Average Sligh Oxidation Numbers					
	Oil No. 1		Oil No. 2		Oil No. 3	
	A.S.T.M. Naphtha	Laboratory Naphtha	A.S.T.M. Naphtha	Laboratory Naphtha	A.S.T.M. Naphtha	Laboratory Naphtha
No. 1	7.1	7.2	26.7	29.4	42.0	44.5
No. 2	9.0	10.0	31.3	29.3	45.7	43.7
No. 3	10.2	10.9	36.7	35.5	51.2	51.5
No. 4	7.7	7.4	28.2	27.5	44.2	41.1
No. 5	7.5	3.9[a]	25.0	19.9[a]	46.5	40.8[a]
No. 6	7.8	7.3	29.0	24.1	41.3	39.5
No. 7	9.0	21.0[b]	28.7	35.3[b]	45.0	61.0[b]
No. 8	9.4	....	27.7	....	43.7	....
No. 9	8.5	....	32.3	29.7	59.7	51.3
No. 10	9.8	11.3	30.9	35.8	46.6	48.9
Grand average	8.6	9.0	29.7	30.2	46.6	45.8

[a] Normal heptane.

[b] Casinghead gasoline prepared to give Sligh oxidation numbers comparable with those obtained with a selected sample of "petroleum ether, U.S.P."

In addition to the values reported, each laboratory was requested to give detailed information regarding the procedure used in making the determinations. On examination, very close uniformity of procedure was found and the subcommittee recommends that the more detailed description of the method appearing in Appendix I be published for information.

The subcommittee is of the opinion that the major source of uncertainty in the method is the filtering medium and a further investigation of this point is in progress.

Respectfully submitted on behalf of the subcommittee,

O. C. BRIDGEMAN,
Chairman.

APPENDIX I

PROPOSED METHOD OF TEST FOR OXIDATION NUMBER OF LUBRICATING OILS BY THE SLIGH METHOD

This is a **proposed method** and is published as information only. Suggestions for revision are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

APPARATUS

1. The apparatus required consists of oxidation flasks, an oxidation bath, oil pipettes, Erlenmeyer flasks, Gooch crucibles, suction flasks and accessories, an electric oven and an analytical balance, conforming to the requirements of the following Paragraphs (*a*) to (*f*):

(*a*) *Oxidation Flasks.*—The oxidation flasks shall be special long-necked flasks with ground-glass stoppers and convection plugs, conforming to the dimensions shown in Fig. 1. The convection plugs shall be interchangeable in the flasks. Each oxidation flask and stopper shall be numbered for identification.

It is essential that the stopper shall be accurately ground into the neck of the oxidation flask. This may be tested by seating the stopper with a drop of naphtha on the ground surface. If any motion of the thin film of naphtha between the ground surfaces is observed when a lateral force is applied to the top of the stopper, the fit is unsatisfactory.

Stopper clamps shall be provided, which may be made from No. 15 B. & S. gage phosphor-bronze spring wire, or from any other suitable material. The clamp should exert a total force of about 2 lb. on the stopper. That portion of the clamp encircling the neck of the flask just below the bead shall be cushioned with any suitable material to avoid localized pressure which might cause breakage of the flask.

(*b*) *Oxidation Bath.*—A well-stirred oil bath capable of being maintained electrically at a temperature of 200 C. ± 1 C. shall be used for the oxidation experiments. The bath shall be thermally insulated, and the circulation of the oil shall be such that any temperature gradients between the oil in different parts of the bath shall be less than 1 C. The bath should preferably be of circular form, 11 in. in inside diameter and 8 in. in depth. A bath of this size will accommodate six oxidation flasks. Clamps or supports to hold the flasks in a vertical position shall be provided, and a well-fitted cover should be used to reduce the rate of deterioration of the bath oil and to protect the greased stoppers in the flasks from overheating. It is important that the upper part of the flask neck be kept cool, since leakage of oxygen almost invariably results if the stopcock grease used becomes hot enough to flow. Thermal insulation of the top of the bath with $\frac{1}{4}$-in. asbestos board may be used to assist in keeping the greased seals cool.

The type of bath shown in Fig. 2 has been found to be satisfactory. Such a bath requires an electrical input of from 200 to 300 w. to maintain a temperature of 200 C.

The oil used in the oxidation bath should have a high flash point in order to minimize the fire hazard, and should have a high resistance to oxidation.

(*c*) *Oil Pipettes.*—The oil pipettes shall be of glass and shall conform to the dimensions shown in Fig. 1. The upper part of the pipette may be graduated, if desired, in 0.1-ml. subdivisions, covering the range from 11.0 to 13.5 ml. In this case, the first and each succeeding 1-ml. and 0.5-ml. line shall be longer than the intermediate lines and the graduations shall be numbered at the 11, 12, 13 and 13.5-ml. marks.

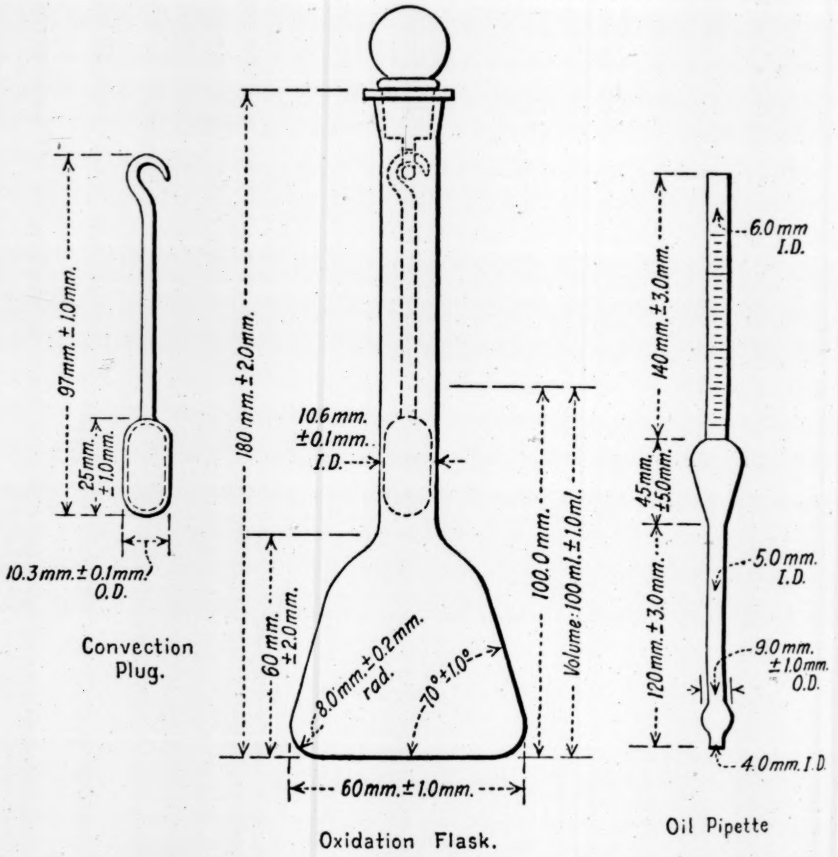
97 mm. ± 1.0 mm.
25 mm. ± 1.0 mm.
10.3 mm. ± 0.1 mm. O.D.
Convection Plug.
180 mm. ± 2.0 mm.
10.6 mm. ± 0.1 mm. I.D.
60 mm. ± 2.0 mm.
8.0 mm. ± 0.2 mm. rad.
70° ± 1.0°
100.0 mm.
Volume: 100 ml. ± 1.0 ml.
60 mm. ± 1.0 mm.
Oxidation Flask.
6.0 mm I.D.
140 mm. ± 3.0 mm.
45 mm. ± 5.0 mm.
5.0 mm. I.D.
120 mm. ± 3.0 mm.
9.0 mm. ± 1.0 mm. O.D.
4.0 mm. I.D.
Oil Pipette

FIG. 1.—Oxidation Flask and Oil Pipette.

(*d*) *Erlenmeyer Flasks.*—The Erlenmeyer flasks shall have a capacity of about 125 ml. and shall be fitted with ground-glass stoppers. A mark shall be etched on the side of each flask indicating a volume of 100 ml.

(*e*) *Gooch Crucibles.*—The Gooch crucibles shall be of the ordinary variety, size No. 3 (25 ml.), of porcelain with perforated bottoms. The crucibles shall be marked for identification, which may be done in any convenient manner provided, however, that the marking material does not vaporize at a temperature of 110 C.

(*f*) *Suction Flasks and Accessories.*—A suction flask shall be provided fitted with a funnel adapter for the Gooch crucibles. Suction shall be applied under a reduced pressure of about 8 cm. of mercury. A three-way stopcock shall be inserted in the line between the suction flask and the pressure regulator so that air may be let into the suction flask at the completion of the filtration.

(*g*) *Electric Oven.*—An electric oven is required which can be maintained at a constant temperature of about 105 C.

(*h*) *Balance.*—An analytical balance having a sensitivity of 0.1 mg. shall be employed for weighing the Gooch crucibles. If desired, a balance having a sensitivity of 0.01 g. may be used for weighing the oil samples.

MATERIALS

2. (*a*) *Asbestos Suspension.*—The asbestos suspension for use in the preparation of the filters shall consist of about 6 g. of finely divided asbestos fiber suspended in 1 liter of distilled water. The suspension shall be made up by shaking the asbestos in water until the bundles of fiber are completely disintegrated. The fine suspension should then be decanted from the small amount of coarse fiber which settles rapidly to the bottom of the vessel. Acid-washed short fiber is suitable for this work and disintegrates into a fine suspension more rapidly than does the more expensive long-fiber material.

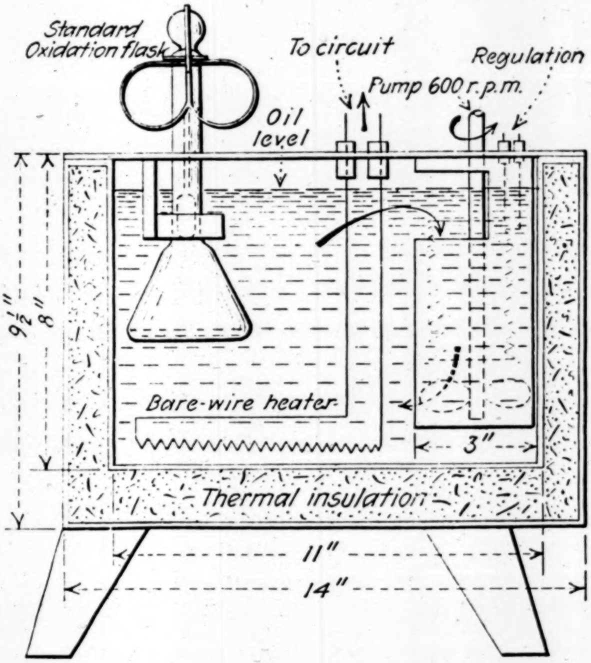

FIG. 2.—Oil Bath for Sligh Oxidation Test.

(*b*) *Stopcock Grease.*—The stopcock grease employed on the ground stoppers of the oxidation flasks shall be of medium or hard grade as required to maintain the seal under the operating conditions. A grease made of 72 per cent of petrolatum, 16 per cent of pure gum rubber and 12 per cent of paraffin wax cooked at 200 C. has proven satisfactory.

(*c*) *Precipitation Naphtha.*—The precipitation naphtha employed shall meet the specifications for naphtha used in determining the precipitation number of lubricating oils, as prescribed in the Standard Method of Test for Precipitation Number of Lubricating Oils (A.S.T.M. Designation: D 91) of the American Society for Testing Materials.[1]

PROCEDURE

3. (*a*) Weigh a clean, dry oxidation flask to 0.01 g. and by means of the oil pipette transfer 10 g. ± 0.1 g. of oil to the flask. Care shall be taken that none of the oil comes in contact with the neck of the flask. The stopper of the flask shall now be slightly greased and the convection plug attached. By means of a glass tube inserted through the neck of the flask, oxygen from a tank shall be allowed to flow into the flask at the rate of about 2 liters per minute. After all air has been displaced by oxygen, which should take about 30 sec., the glass tube shall be removed and the stopper carrying the convection plug quickly inserted, seated and clamped.

(*b*) The flask shall now be secured in place in the oxidation bath which has already been brought to a temperature of 200 C. The level of the bath liquid shall be about 1 in. above the body of the flask. The flask shall be allowed to remain in the oxidation bath for 2½ hr. and during this period the temperature shall be maintained at 200 C. ± 1 C. The flask shall then be removed and allowed to cool and any of the bath oil remaining on the outside of the flask shall be washed off with gasoline or a mixture of gasoline and benzol.

(*c*) After the outside of the flask has been dried, the flask shall be opened and any stopcock grease left on the ground surface shall be carefully wiped off with a clean cloth. A 50-ml. portion of precipitation naphtha shall be added to the oxidized oil and mixed thoroughly with it by swirling. This solution shall be transferred quantitatively to a glass-stoppered Erlenmeyer flask, the oxidation flask being rinsed out carefully with successive small portions of precipitation naphtha which may conveniently be added from a wash bottle. The solution shall then be made up to a total volume of 100 ml. by further addition of precipitation naphtha. The ground-glass stopper shall then be inserted in the Erlenmeyer flask and the solution thoroughly mixed by shaking, after which the flask shall be allowed to stand at a temperature of 25 C. ± 2 C. for a period of 1 hr.

(*d*) A Gooch crucible shall be prepared for the filtration process by pouring into it about 20 ml. of the asbestos suspension. After being allowed to drain for a few minutes to permit the formation of a thin mat on the bottom of the crucible, this mat shall be sucked dry in the suction flask. If desired, the filter may be washed with ethyl alcohol to hasten the drying. If pure ethyl alcohol is not available, denatured alcohol containing 90 per cent ethyl and 10 per cent methyl alcohol may be employed. Alcohol containing any denaturant other than methyl alcohol should not be used. The crucible shall then be dried in the electric oven at 105 C. for a period ranging from 30 to 60 min., as required, to reach constant weight. After the crucible has been allowed to cool in a desiccator it shall be weighed to 0.1 mg. The weighed crucible shall now be placed in the suction flask and the clear solution above the precipitate in the Erlenmeyer flask shall be poured onto the filter. When practically all of the clear solution has been decanted, the oil on the side of the filter shall be carefully washed off with a stream of precipitation naphtha from a wash bottle. The precipitate shall then be quantitatively transferred to the filter, using a stiff bristle brush if necessary to detach portions of the precipitate from the walls of the flask. If a brush is used any precipitate adhering to the brush must be carefully washed off into the filter by means of precipitation naphtha. Finally, the precipitate on the filter shall be thoroughly washed with precipitation naphtha to remove traces of oil and then shall be sucked dry. The crucible shall be dried in the electric oven at 105 C. for 15 to 30 min. and after cooling in a desiccator it shall be weighed to 0.1 mg.

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[1] 1935 Supplement to Book of A.S.T.M. Standards, p. 186.

4. *Oxidation Number.*—The oxidation number of the oil is numerically equal to the number of milligrams of precipitate obtained from a 10.0-g. sample of the oil (Note).

NOTE: *Example.*—If the weight of precipitate from a 10.0-g. sample of oil is 20.5 mg., the oxidation number of the oil is 20.5.

5. (*a*) *Cleaning Apparatus.*—Immediately after use the oxidation flask shall be carefully cleaned. For this purpose, it should first be rinsed with chloroform, benzol or carbon tetrachloride and allowed to drain in an inverted position until dry. The flask shall then be filled with sulfuric-acid cleaning solution and allowed to stand for at least 12 hr. unless the cleaning solution is kept hot, in which case the time required for cleaning can be reduced by an amount depending upon the temperature. The cleaning solution shall than be removed and the flask rinsed several times with tap water and finally with distilled water. The flask may be dried on a draining rack, or in the electric oven by inserting a glass tube into the flask through which air is drawn by suction.

(*b*) The convection plugs and the glass stoppers of the oxidation flasks shall likewise be cleaned by immersion in sulfuric-acid cleaning solution for the appropriate period of time, followed by thorough washing with water and drying. The common practice of rinsing with alcohol and ether to hasten drying should not be followed due to the explosive nature of traces of residue which may be left by these materials. Thorough cleaning of the oxidation flasks, stoppers and convection plugs is essential and shall be performed each time a test is run, since traces of oxidized oil remaining in the flask may produce erroneous results in the succeeding test.

(*c*) The Erlenmeyer precipitation flasks shall be cleaned by rinsing with benzol or carbon tetrachloride followed by rinsing with precipitation naphtha. From time to time, it may be necessary to clean them with sulfuric-acid cleaning solution in order to remove stains. After each test the asbestos pads in the Gooch crucibles shall be removed and any stains wiped off with a clean cloth moistened in benzol or carbon tetrachloride, after which the crucible shall be rinsed with precipitation naphtha and dried.

6. *Sources of Error.*—The largest source of error in the oxidation test appears to be attributable to loss of oxygen from the flask during the test. This may be due to a poor fit of the stopper in the neck or to overheating of the neck of the flask due to inadequate insulation of the top of the oxidation bath. Erratic results may also be due to imperfect cleaning of the oxidation flasks or to accidental contamination after cleaning.

APPENDIX II

DIESEL-FUEL-OIL CLASSIFICATION

Manufacturers and users of Diesel engines, as well as petroleum refiners and distributors, have long felt the need for some classification differentiating types of fuel oils suitable for Diesel engines. The classification shown in Table I, covering five grades of oil, was developed by Technical Committee C on Fuel Oils (Including Diesel Fuel) of Committee D-2 on Petroleum Products and Lubricants in an attempt to supply this need. This classification was first presented in June, 1934, and has been revised as a result of suggestions since received.

TABLE I.—DIESEL-FUEL-OIL CLASSIFICATION.

Grade of Diesel Fuel	Flash Point, deg. Fahr.	Water and Sediment, per cent by Volume	Viscosity, seconds			Carbon Residue, per cent by weight	Ash, per cent by weight	Pour Point, deg. Fahr.	Sulfur, per cent by weight	Ignition Quality
			Saybolt Universal (at 100 F.)		Saybolt Furol (at 122 F.)					
	Min.[a]	Max.	Min.[b]	Max.	Max.	Max.	Max.	Max.[c]		
No. 1-D	115 or legal	0.05	32	50	...	0.2	0.02	35	[d]	[e]
No. 3-D	150	0.1	32	70	...	0.5	0.02	35	[d]	[e]
No. 4-D	150	0.6	..	250	...	3.0	0.04	35	[d]	[e]
No. 5-D	150	1.0	..	...	100	6.0	0.08	..	[d]	..
No. 6-D	Limits for No. 6-D fuel are the same as for No. 6 oil in the Tentative Specifications for Fuel Oils (A.S.T.M. Designation: D 396 - 34 T) of the American Society for Testing Materials,[1] unless modified by special negotiations between buyer and seller.									

[a] Minimum flash point, as stated or as required by local fire regulations, Fire Underwriters or state laws.

[b] For viscosities below 35 sec. at 100 F. Saybolt Universal, other methods than that by the Saybolt Universal viscosimeter at 100 F. may be used and the results converted.

[c] Lower pour points may be specified whenever required by local temperature conditions to facilitate storage and use, although it should not be necessary to specify a pour point of less than 0 F.

[d] So far as known, sulfur content need not be considered as regards combustion characteristics. However, when sulfur content is of consequence—as, for instance, in fuel for engines in intermittent service—the following limits are suggested:

Fuel No. 1-D........ 1.5 per cent max.
Fuel No. 3-D........ 1.5 per cent max.
Fuel No. 4-D........ 2.0 per cent max.
Fuel No. 5-D........ 2.0 per cent max.

[e] See Table II and discussion in Paragraph (*h*) of the text.

TABLE II.—IGNITION QUALITY.[a]

	Oil Grades		
	No. 1-D	No. 3-D	No. 4-D
Cetane number, min	50	40	30
Diesel index number, min	45	30	20
Viscosity-gravity number, max	0.86	0.89	0.91
Boiling-point - gravity number, max	188	195	200

[a] The values in Table II are equivalent within the limits of error of the test methods used. As the correlations between indexes and between any index and engine operation in the field are not completely established as yet, these values should be used in an approximate way only.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 882 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 696.

It is not the intention of the committee that this classification should be used as purchase specifications; but rather that fuels purchased be correlated according to the proposed classification in order to determine its usefulness. A series of Diesel-fuel-oil specifications should evolve as a result of this program. Criticism and comment should be forwarded to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 50 West 50th Street, New York, N. Y.

METHODS OF TESTING

The properties listed in this classification are determined in accordance with the following methods of testing:

(a) *Flash Point.*—In absence of legal or local requirements, the minimum flash point shall be determined in accordance with the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93) of the American Society for Testing Materials.[1]

(b) *Water and Sediment.*—Standard Method of Test for Water and Sediment of Petroleum Products (A.S.T.M. Designation: D 96) of the American Society for Testing Materials.[2]

(c) *Viscosity.*—Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[3]

(d) *Carbon Residue.*—Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (A.S.T.M. Designation: D 189) of the American Society for Testing Materials.[4]

(e) *Ash.*—Place 10 g. of the fuel oil in a weighed uncovered platinum crucible of a capacity not greater than 100 ml. and heat gently with a Bunsen burner until the oil fires and continues to burn when the flame of the burner is applied to the surface of the oil. Allow the oil to burn without further application of heat. The oil will continue to burn until practically all of it has disappeared. The time required will be about 50 min. Then place the platinum crucible in a gas or electric furnace and heat to a bright red heat until all carbon is consumed. Cool, weigh and report the residue as ash expressed as a percentage of the original 10-g. sample.

(f) *Pour Point.*—Standard Method of Test for Cloud and Pour Points (A.S.T.M. Designation: D 97) of the American Society for Testing Materials.[5]

(g) *Sulfur.*—Standard Method of Test for Sulfur in Petroleum Oils by Bomb Method (A.S.T.M. Designation: D 129) of the American Society for Testing Materials.[6]

(h) *Ignition Quality.*—According to present opinion, combustion knock in a fuel-oil-injection engine is caused by the accumulation of fuel in its cylinders prior to ignition. Even under conditions that insure ignition, the fuel may not ignite instantaneously but only after a definite delay. The longer this delay, the more fuel accumulates in the cylinders, which then burns unevenly, finally causing audible knock. If the delay is extreme, the engine will fail to operate with the fuel. It is significant that every factor which tends to aggravate knocking in a spark-ignition gasoline engine tends to suppress it in Diesel engines. Fuels of paraffin base consisting chiefly of saturated straight-chain hydrocarbons give the smoothest combustion in general, while naphthenes and aromatics burn roughly at low compression ratios. It is known that highly cracked products give trouble and also that the amount of trouble is increased as the speed of the engine is increased. Turbulence in the charge mixture reduces the delay period and turbulence is a controlling factor in engine speed. It is now generally agreed that ignition quality is one of the most important characteristics of Diesel fuels.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 805.
[2] 1935 Supplement to Book of A.S.T.M. Standards, p. 190.
[3] 1933 Book of A.S.T.M. Standards, Part II, p. 880.
[4] *Ibid.*, p. 757.
[5] 1934 Supplement to Book of A.S.T.M. Standards, p. 117.
[6] *Ibid.*, p. 124.

The committee realizes the impossibility of reducing all types and designs of engines to a common rating for fuel-burning characteristics. Engine factors, such as combustion-chamber design, turbulence, spray characteristics, compression ratio, injection timing, and engine speed, vary greatly in different engine makes. Tests of ignitibility on various types of engines have no theoretical significance but have provided practical data for the types and sizes of engines on which the tests were performed. Fuel characteristics are based on a study of field-engine performance correlated with laboratory ratings of various test fuels. Ignitibility, one of the most important characteristics from the standpoint of satisfactory engine operation, has been expressed by such indices of performance as cetane number, Diesel index number, viscosity-gravity number, and boiling-point-gravity number.

CETANE NUMBER.—Cetene number was first proposed by Boerlage and Broeze of the Bataafsche Petroleum Maatschappij[1] and is the percentage of cetene in a blend of cetene and alphamethylnaphthalene which has the same ignition quality (measured in a specified engine under a definite set of engine conditions) as the fuel under test. It has been found that more reliable results may be possible when using cetane rather than cetene. For this reason, this classification substitutes the cetane number, which is determined and expressed in the same manner as the cetene number, namely, as the percentage of cetane in a blend of cetane and alphamethylnaphthalene.

DIESEL INDEX NUMBER.—Diesel Index number is calculated from aniline point and A.P.I. gravity by the following formula:

$$\text{Diesel Index Number} = \frac{(\text{A.P.I. gravity at 60 F.}) \times (\text{aniline point in deg. Fahr.})}{100}$$

Aniline Point is the lowest temperature at which equal parts by volume of freshly distilled aniline and the test sample of oil are completely miscible. It is determined by heating such a mixture in a jacketed test tube to a clear solution and noting the temperature at which turbidity appears as the mixture is cooled.

For A.P.I. Gravity see the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287) of the American Society for Testing Materials.[2]

VISCOSITY - GRAVITY NUMBER.—Viscosity - Gravity Number was first proposed by Hill and Coats in 1928 and a modification was later advanced by Moore and Kaye in 1934.[3] The number is determined by the following equation:

$$G = 1.082\,A - 0.0887 + (0.776 - 0.72A) \times \log\log\,(KV - 4)$$

where G = specific gravity at 60 F.
A = viscosity - gravity constant
KV = kinematic viscosity in millistokes at 100 F.

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[1] Boerlage and Broeze, "Ignition Quality of Diesel Fuels as Expressed in Cetene Numbers," *Journal*, Soc. Automotive Engrs., July, 1932.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 819.

[3] Moore and Kaye, "Practical Evaluation of the Ignition Characteristics of Diesel Fuel Oils," *Oil and Gas Journal*, p. 108, November 15, 1934.

BOILING-POINT - GRAVITY NUMBER.—Boiling-Point - Gravity Number was first proposed by E. A. Jackson[1] in 1935. Generally speaking, the larger the number, the more naphthenic the oil, and the lower the number, the more paraffinic the oil. The number is determined by the following equation:

$$G = A + (68 - 0.703A) \log B.P.$$

where G = A.P.I. gravity in degrees
A = Boiling-point - gravity constant
$B.P.$ = 50 per cent boiling point on A.S.T.M. distillation curve in degrees Cent.

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[1] E. A. Jackson, "Boiling-Point - Gravity Constant is Index of Lubricating Oil Characteristics," *Oil and Gas Journal*, March 21, 1935.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS

Committee D-4 on Road and Paving Materials, in an appendix to its 1934 annual report as preprinted for the annual meeting, presented five new proposed specifications for emulsified asphalt, one new method of test for separation of liquid asphaltic products, and also proposed revised methods of testing emulsified asphalts. After making certain changes in these at the annual meeting, they were subsequently approved[1] by letter ballot of the committee and were then referred to Committee E-10 on Standards with the recommendation that they be issued by the Society as tentative. At a meeting of Committee E-10 on August 22, 1934, these recommendations were accepted and the new specifications and method and the revised methods, the titles and designations of which are as follows, have been published in the 1934 *Proceedings:*[2]

Tentative Specifications for:
- Emulsified Asphalt (for Coarse Aggregate Plant Mixes) (D 397 – 34 T)
- Emulsified Asphalt (for Retread and Coarse Aggregate Mixes) (D 398 – 34 T)
- Emulsified Asphalt (Heavy Premix—Summer Grade) (D 399 – 34 T)
- Emulsified Asphalt (Heavy Premix—Winter Grade) (D 400 – 34 T)
- Emulsified Asphalt ((Quick-Setting) for Penetration and Surface Treatment) (D 401 – 34 T)

Tentative Method of Test for Separation of Liquid Asphaltic Products (D 402 - 34 T)

Tentative Methods of Testing Emulsified Asphalts (D 244 – 34 T)

On the recommendation of its Subcommittee B-4 on Ductility, Committee D-4 at its meeting in June, 1934, approved the following editorial changes in the Tentative Method of Test for Ductility of Bituminous Materials (D 113 – 32 T). These changes were submitted to the Society subsequent to the annual meeting and have been incorporated in the method as published in the 1934 Book of A.S.T.M. Tentative Standards, page 725:

Section 2.—The specified dimension between clips was changed to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

Distance between clips.................................2.97 to [3.06] *3.03*

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[1] In submitting these specifications and methods to Committee E-10 on Standards, Committee D-4 reported the following results of the letter ballot vote of a total of 56 ballots returned from a committee membership of 95: On each of the five Tentative Specifications for Emulsified Asphalt, 44 affirmative, 5 negative and 7 ballots marked "not voting"; Tentative Method of Test for Separation of Liquid Asphaltic Products (D 402 - 34 T), 52 affirmative, 1 negative and 3 ballots marked "not voting"; Tentative Methods of Testing Emulsified Asphalts (D 244 – 34 T), 46 affirmative, 4 negative and 6 ballots marked "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 916, 918, 920, 922, 924, 938, 926 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 684, 686, 688, 690, 692, 728, 711.

Figure 1.—The illustration of the mold for the ductility test specimen was changed by the inclusion of an over-all dimension of "11.9 cm. ± 0.1 cm." between the outside extremities of the holes in the mold, and by the inclusion of a dimension showing the width of the briquet at the clips as "3.15 to 3.25 cm." The following note was also included with the illustration of the mold:

> Note.—The opening in the end of each clip, as indicated by "x," shall be half an ellipse having a transverse axis of 3.2 cm. ± 0.05 cm. and half of the longitudinal axis shall be 1.45 to 1.55 cm.

The committee is recommending the adoption as standard of the Tentative Method D 113 with a further revision as given later in this report.

Recommendations Affecting Standards

I. *Proposed Tentative Standards:*

Proposed Tentative Volume Correction Table for Asphaltic Products.—Committee D-4 joins with Committee D-8 on Bituminous Waterproofing and Roofing Materials in recommending that the tables designated as Group 0 and Group 1 in the Standard Abridged Volume Correction Table for Petroleum Oils (D 206 – 34)[1] be tentatively approved as a Volume Correction Table for Asphaltic Products. These tables are now in common use in the asphalt industry.

Proposed Tentative Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates.—This method, appended hereto,[2] was prepared by a joint Conference Committee on Silt and Loam, appointed by Committee C-9 on Concrete and Concrete Aggregates and Committee D-4.[3] It has been submitted to letter ballot of Committee C-9 and is now recommended by Committee D-4 for publication as tentative, with the following explanatory statement:

> The proposed tentative method was prepared as a replacement of the existing Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 21) and Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 28) for the following reasons:
>
> 1. To eliminate two existing standard methods which essentially are for the same purpose but which differ somewhat in technique and which may not give comparable results.
>
> 2. To define with precision the maximum size of the fine material determined by the test and thus eliminate such indefinite terms as clay, silt and loam.
>
> 3. To eliminate the sedimentation methods of the two existing standards. To secure accurate results by means of sedimentation it is necessary to control several variables which are not controlled in either of the existing standards. The control

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 127.

[2] See p. 832.—Ed.

[3] Modifications in the method were presented to the Society at the annual meeting, see Summary of Proceedings, p. 19.—Ed.

necessary for an accurate sedimentation test is a refinement which is not warranted by the purpose of these tests. The desired results may be secured by the simple washing test described in the proposed tentative method.

Attention should be called to the fact that the proposed method will not necessarily give results comparable with those obtained with either of the existing standard methods. The differences will depend on the grading and amount of the fine material and on the variations in the technique which are possible in conducting the tests in accordance with the present standard methods. Generally speaking, the new method may be expected to show somewhat higher percentages of fine material than the present standards and the replacement of these by the proposed method may require some revision in the test limits of existing standard specifications.

A number of tests made in one laboratory on representative sands for portland-cement concrete gave, with the proposed method, percentages of material finer than the No. 200 (74-micron) sieve which averaged about 0.3 per cent higher than the fine material determined by the present standard decantation test.

While it appears that relatively few commercial sands as now produced would be affected by the proposed change in the test method, recognition of the increased loss should probably be made in specification requirements to avoid the exclusion of what are, at present, border-line materials. For example, the usual limit for concrete sand of 3.0 per cent removed by decantation might be changed to 3.5 per cent of material finer than the No. 200 (74-micron) sieve, or to some other value which might be established by further tests.

Committee D-4 believes that after additional data have been secured, this method may be substituted for existing requirements in certain specifications, resulting in withdrawal of the Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 21),[1] and Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 28).[1]

II. Proposed Revision of Standard:

Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 30).[2]—In this method the shield for the distillation flask is not provided with windows but is otherwise identical with the shield described in the Tentative Method of Test for Separation of Liquid Asphaltic Products (D 402 – 34 T). In order to permit the same shield to be used for both methods, the committee recommends that the following note be added to the standard method. Because it is felt that this will in no way modify the results of tests and is merely a matter of laboratory efficiency, it is recommended that this change be made as an editorial matter and this note added to the methods immediately:

Section 4.—Add the following note at the end of this section:

NOTE.—The use of the shield with observation windows (see the Tentative Method of Test for Separation of Liquid Asphaltic Products (A.S.T.M. Designation: D 402 – 34 T) of the American Society for Testing Materials) is permissible.

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[1] 1933 Book of A.S.T.M. Standards, Part II, pp. 950, 951.

[2] *Ibid.*, p. 953.

III. Proposed Revision of Tentative Standards:

Tentative Method of Test for Residue of Specified Penetration (D 243 - 32 T).[1] To bring this method in closer conformity with customary practice, the committee recommends that it be revised as follows and continued as tentative:

Section 8.—Change the last sentence to read as follows by the addition of the italicized words and figures:

> The penetration of the residue shall then be determined in accordance with the Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5) of the American Society for Testing Materials, ***with the exception that the 6-oz. container specified in Section 3, in which the evaporation has been conducted, shall be used instead of the 3-oz. container specified in the Standard Method D 5.***

Tentative Methods of Testing Emulsified Asphalts (D 244 - 34 T).[2]—To eliminate an unnecessary requirement in these methods for apparatus which is not used, the committee recommends that they be revised as follows and continued as tentative:

Section 23.—Omit Paragraph (*a*) which reads as follows, relettering the remaining paragraphs accordingly:

> (*a*) *Sieves.*—The No. 10 sieve, brass frame, of the U. S. Standard Sieve Series, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.

IV. Proposed Adoption of Tentative Standard as Standard:

Tentative Method of Test for Ductility of Bituminous Materials (D 113 - 32 T).[3]—To meet the criticisms of apparatus manufacturers, it is recommended that the following footnote be included in the method in connection with Section 2 and Fig. 1, and that with this change the method be referred to the Society for adoption as standard:

> The over-all dimension of 11.9 cm. ± 0.1 cm. in Fig. 1 shall be waived until January 1, 1939, provided the actual dimension is between 11.2 and 11.9 cm. This exception is allowed in order to avoid working a hardship upon apparatus manufacturers.

V. Tentative Standards Continued as Tentative:

In connection with the tentative standards for which it is responsible and which have been published for three or more years without revision, Committee D-4 regrets that it is unable at this time to recommend their adoption as standard. It hopes, however, to include definite recommendations regarding them in its next annual report. It is accordingly recommended that they be continued as tentative for another year.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 784 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 734.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 926 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 711.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 32 ,Part I, p. 781 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 725.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee B-12 on Abrasion of Coarse and Fine Aggregates (Stanton Walker, chairman).—During the past year this subcommittee has carefully investigated a new abrasion test which it is believed will eventually be substituted for the present Standard Method of Test for Abrasion of Rock (D 2 – 33). As a result of this investigation a new Proposed Method of Test for Abrasion of Coarse Aggregate has been prepared which Committee D-4 believes is of sufficient importance to warrant its publication as information, and it is, therefore, appended to this report.

Subcommittee D-5 on Soils for Highway Construction (C. A. Hogentogler, chairman).—This subcommittee, which was organized during the past year, has prepared eight new methods of test for soils as follows. It is expected that these will shortly be submitted to letter ballot of Committee D-4:[1]

Proposed Methods of:

Surveying and Sampling Soils
Preparing Soils for Test
Determining the Liquid Limit of Soils
Determining the Plastic Limit and Plasticity Index of Soils
Determining the Centrifuge Moisture Equivalent of Soils
Determining the Shrinkage Factors of Soils
Determining the Field Moisture Equivalent of Soils
Mechanical Analyses of Soils

Subcommittee D-4 on Asphalt Planks (R. R. Litehiser, chairman).—This subcommittee has recently prepared specifications for asphalt plank which it is expected will soon be acted upon by Committee D-4.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 88 members; 60 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Tentative Volume Correction Table for Asphaltic Products	51	0	9
Tentative Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates	54	0	6
II. PROPOSED REVISION OF STANDARD			
Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 30), editorial change	49	0	11
III. PROPOSED REVISION OF TENTATIVE STANDARDS			
Method of Test for Residue of Specified Penetration (D 243 – 32 T)	51	0	9
Methods of Testing Emulsified Asphalts (D 244 – 34 T)	48	0	12
IV. PROPOSED ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Test for Ductility of Bituminous Materials (D 113 – 32 T), as revised	50	1	9

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[1] See Editorial Note, p. 349.—ED.

This report has been submitted to letter ballot of the committee, which consists of 88 members; 60 members returned their ballots, of whom 57 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

M. H. ULMAN,
Chairman.

PRÉVOST HUBBARD,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-4 on Road and Paving Materials presented to the Society on August 22, 1935, through Committee E-10 on Standards the following proposed tentative methods:

Proposed Tentative Methods of:

- Surveying and Sampling Soils for Use in Place as Subgrades for Highways
- Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants
- Mechanical Analysis of Soils
- Test for Liquid Limit of Soils
- Test for Plastic Limit and Plasticity Index of Soils
- Test for Centrifuge Moisture Equivalent of Soils
- Test for Field Moisture Equivalent of Soils
- Test for Shrinkage Factors of Soils

The above methods of test were accepted by Committee E-10 and appear respectively on pp. 940 to 982, inclusive.

APPENDIX

PROPOSED METHOD OF TEST

FOR

ABRASION OF COARSE AGGREGATE BY THE USE OF THE LOS ANGELES TEST MACHINE[1]

This is a **proposed draft** and is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This method of test is intended for determining the abrasive resistance of crushed rock, crushed slag, uncrushed gravel, and crushed gravel (Note).

NOTE.—Ledge rock, hand-broken into approximately cubical fragments of the different sizes shown, when tested by this method, has been found to have a loss of approximately 85 per cent of that for crushed rock of the same quality.

Apparatus

2. The machine shall consist of a hollow iron drum, having inside dimensions of 20 in. in length and 28 in. in diameter, rotating on a horizontal axis. The opening in the cylinder shall be closed dust-tight with a removable cover bolted into place and having a shelf which projects $3\frac{1}{2}$ in. into the drum and extends the full length of the drum. The testing machine shall conform in all of its essential characteristics to the plan shown in Fig. 1.

Abrasive Charge

3. An abrasive charge composed of cast-iron spheres approximately $1\frac{7}{8}$ in. in diameter, weighing between 400 and 450 g. each, and conforming to the requirements in Section 24 of the Standard Specifications for Paving Brick (A.S.T.M. Designation: C 7) of the American Society for Testing Materials[2] shall be used with the test sample. A charge of 12 spheres weighing 5000 g. ± 50 g. shall be used with the grading *A* described in Section 4, and a charge of 11 spheres weighing 4583 g. ± 50 g. shall be used with the grading *B* described in Section 4.

Test Sample

4. The test sample shall consist of 5000 g. of clean, dry aggregate and

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[1] Under the standardization procedure of the Society, this method is under the joint jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 113.

shall conform to either of the following gradings. The grading used shall be that most nearly representing the aggregate furnished for the work.

Sieve Size, in. (Square Openings) Passing	Retained on	Weight, g. Grading *A*	Weight, g. Grading *B*
1½	1	1250	0
1	¾	1250	0
¾	½	1250	2500
½	⅜	1250	2500

Procedure

5. The test sample and the abrasive charge shall be placed in the abrasion machine and the machine rotated at 30 to 33 r.p.m. for 500 revolutions in such a direction that the charge shall be caught by the inside of the angle forming the shelf, At the completion of the test, the material shall be removed from the machine and sieved on a No. 12 sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1] The material retained on the sieve shall be washed, dried, and weighed to the nearest gram (Note).

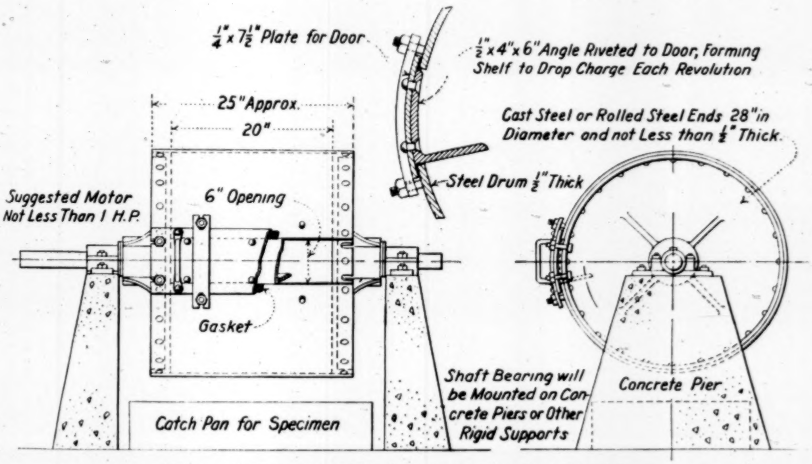
¼" x 7½" Plate for Door
½" x 4" x 6" Angle Riveted to Door, Forming Shelf to Drop Charge Each Revolution
25" Approx.
20"
Cast Steel or Rolled Steel Ends 28" in Diameter and not Less than ½" Thick.
Steel Drum ½" Thick
Suggested Motor Not Less Than 1 H.P.
6" Opening
Gasket
Shaft Bearing will be Mounted on Concrete Piers or Other Rigid Supports
Concrete Pier
Catch Pan for Specimen

FIG. 1.—Los Angeles Abrasion Testing Machine.

NOTE.—Attention is called to the fact that valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions; when this determination is made care should be taken to avoid loss of any part of the sample; the entire sample, including the dust of abrasion, shall be returned to the testing machine for the completion of the test.

Calculation

6. The difference between the initial weight and final weight of the test sample shall be expressed as a percentage of the initial weight. This value shall be reported as the percentage of wear.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

REPORT OF COMMITTEE D-5
ON
COAL AND COKE

Committee D-5 on Coal and Coke held one meeting during the year, in Philadelphia, Pa., on March 7, 1935. The Tentative Definition of the Term Coke (D 121 – 30 T) is being continued as tentative pending the formulation of a definition that will be acceptable to both Committee D-5 and Committee D-2 on Petroleum Products and Lubricants. The Tentative Method of Sampling Coke for Analysis (D 346 – 33 T), with some minor revisions, is being recommended for adoption as standard. Definitions of the terms gross calorific value, H_s, and net calorific value, H_i, two optional methods of test for determination of coal grindability, and a method of test for screen analysis of coal are being recommended for publication as tentative.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Methods of Testing (W. A. Selvig, chairman).—A Proposed Method of Test for Agglutinating Value of Coal was published as information with the 1934 report of Committee D-5.[1] Trouble is being experienced in obtaining sand with uniform characteristics for this method of test. Microscopic examination of different shipments of the Ottawa sand used as inert material shows that the sand grains have a more or less frosted surface and this varies in different shipments. Sand having a relatively large amount of grains with frosted surfaces gives higher agglutinating values than does sand with more glossy surfaces. Sands from other sources are being investigated to determine their suitability for use as an inert material in this method of test.

Subcommittee II on Nomenclature and Definitions (H. C. Porter, chairman).—This subcommittee is cooperating with Committee D-2 on Petroleum Products and Lubricants and Committee E-8 on Nomenclature and Definitions to formulate a definition of the term coke that will be satisfactory to the several committees. The subcommittee, in cooperation with the Subcommittee on Definitions of Net and Gross Calorific Values, of Committee E-8, has prepared definitions of the terms gross calorific value, H_s, and net calorific value, H_i which are being submitted for publication as tentative.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 457 (1934).

Subcommittee V on Tolerances (C. A. Lunn, chairman).—This subcommittee held a meeting in New York City, on February 21, 1935. Data are being assembled regarding (1) tolerances as to allowable differences between two laboratories analyzing different portions of coal crushed to pass a No. 60 sieve, (2) tolerances as to allowable differences between two laboratories analyzing different portions of coal crushed to pass a No. 4 sieve, and (3) tolerances as to allowable differences between two laboratories independently sampling the same lot of coal. The subcommittee has concluded not to attempt to establish tolerances in case of different laboratories independently sampling the same lot of coal as the labor and expense of conducting such an investigation is too great to consider undertaking it at this time.

Subcommittee VII on Pulverizing Characteristics of Coal (John Van Brunt, chairman).—A meeting of this subcommittee was held in New York City, on February 21, 1935. Cooperative grindability tests by different methods were made by five laboratories on a series of five coals covering a wide range in grindability. As a result of these tests, the subcommittee has recommended two optional methods of test. One is a ball-mill method; the other makes use of a specially designed machine known as the Hardgrove machine. The ball-mill method has the advantage of low cost of equipment. It was developed by H. F. Yancey, O. L. Furse and R. A. Blackburn[1] of the Seattle Station of the U. S. Bureau of Mines. The Hardgrove-machine method was developed by R. M. Hardgrove[2] of the Babcock & Wilcox Co. This method has the advantage of speed in making the determination. The cooperative grindability investigation showed that these two methods were superior to any of the other methods tested, both in accuracy and ability to duplicate results when different laboratories test the same coal. At a meeting of Committee D-5, on March 7, 1935, these two methods were accepted as tentative subject to approval by letter ballot of the committee.

Subcommittee IX on Coke Sampling (O. O. Malleis, chairman).—At the meeting of Committee D-5, on March 7, 1935, Subcommittee IX recommended that the Tentative Method of Sampling Coke for Analysis (D 346 – 33 T), with some minor revisions in the table of minimum weights of gross samples of coke, be recommended to the Society for adoption as standard. The method respresents what is considered to be the best American practice for sampling coke. Committee D-5 approved the recommendation of the subcommittee.

Subcommittee XI on Coal Friability (R. E. Gilmore, chairman).—Active work on the development of methods for the determination of coal friability was conducted during the past year. The subcommittee is considering two methods of test. One of these methods is a small-jar tumbler method essentially as described in the Bureau of Mines *Report of Investigations No. 3215.*[1] This method uses a sample of 1000 g. of coal of 1 to 1½-in. lumps. The other is a drop shatter test which uses a 50-lb. sample and is similar to the Standard Method of Shatter Test for Coke (D 141 – 23). The small scale tumbler test is considered applicable for testing the relative friability of coal, whereas the shatter test represents more closely the breakage taking place in the commercial handling of coal.

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[1] H. F. Yancey, O. L. Furse and R. A. Blackburn, "Estimation of the Grindability of Coal," *Transactions*, Am. Inst. Mining and Metallurgical Engrs., Vol. 108, p. 267 (1934).

[2] R. M. Hardgrove, "Grindability of Coal," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 54, F.S.P. 37 (1932).

Subcommittee XII on Sampling Coal at Coal Cleaning Plants (T. W. Guy, chairman).—The subcommittee has continued collecting and evaluating data on sampling coal at coal cleaning plants. Two papers were prepared by members of the subcommittee during the past year; namely, "Determining the Correct Weight of Sample in Coal Sampling," by L. S. Kassel and T. W. Guy,[2] and "Variables in Coal Sampling," by J. B. Morrow and C. P. Proctor.[3]

Subcommittee XIII on Mechanical Sampling and Reduction of Samples (J. B. Morrow, chairman).—This is a new subcommittee which will be responsible for the standardization of methods of collection of gross samples by mechanical means and mechanical methods of reducing gross samples to a convenient quantity for transmittal to the laboratory. The present Standard Method of Sampling Coal (D 21 – 16) is a hand sampling method as no details are given concerning mechanical means of sampling. The subcommittee held two meetings in Pittsburgh, Pa., on April 1, 1935, and June 24, 1935. It agreed first to standardize mechanical methods of reducing gross samples to laboratory size, after which it will standardize mechanical methods of collecting gross samples.

RECOMMENDATIONS AFFECTING STANDARDS

I. Proposed Tentative Standards:

Tentative Definitions of the Terms Gross Calorific Value, H_s, and Net Calorific Value, H_i, of Fuels.—The committee submits for publication as tentative the definitions of the terms Gross Calorific Value, H_s, and Net Calorific Value, H_i, as appended hereto.[4]

Tentative Methods of Test for Grindability of Coal.—The committee recommends that the Proposed Tentative Method of Test for Grindability of Coal by the Ball-Mill Method, and the Tentative Method of Test for

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[1] H. F. Yancey and R. E. Zane, "Comparison of Methods for Determining the Friability of Coal," U. S. Bureau of Mines *Report of Investigations No. 3215* (1933).

[2] *Industrial and Engineering Chemistry,* Analytical Edition, Vol. 7, p. 112 (1935).

[3] Presented before the Coal Division of the American Institute of Mining and Metallurgical Engineers, at a meeting held in New York City on February 18, 1935.

[4] See p. 867.—ED.

Grindability of Coal by the Hardgrove-Machine Method,[1] appended hereto, be accepted for publication as tentative.

Tentative Method of Test for Screen Analysis of Coal.—Committee D-5 recommends that the Proposed Tentative Method of Test for Screen Analysis of Coal, appended hereto,[2] be accepted for publication as tentative.

This method was developed and recommended to Committee D-5 for consideration by Subcommittee VII on Defining Coal Sizes and Friability (J. D. Doherty, chairman), of the Technical Committee on Coal Classification of the Sectional Committee on Classification of Coals. The method applies to size testing of all coal with the exception of anthracite, powdered coal as used in boiler plants, and crushed coal as charged into coke ovens, methods for which are already standards of the Society. The method represents the best American practice in size testing of coal to determine the distribution of various sizes in any given lot of coal.

II. Adoption of Tentative Standard as Standard:

Tentative Method of Sampling Coke for Analysis (D 346 – 33 T).[3]—The committee recommends that this method be revised as follows and referred to letter ballot of the Society for adoption as standard:

Section 3.—Change the table in this section from its present form: namely,

Minimum Weights of Gross Samples of Coke

Run-of-oven, Blast-furnace, Foundry, Water-gas, and any coke containing a range of size of pieces made from uncrushed or coarsely crushed coal (more than 10 per cent on ¼-in. square-hole sieve) except coke breeze	500 lb.[a]
Run-of-oven, Blast-furnace, Foundry, Water-gas and any coke containing a range of size of pieces made from crushed coal (not less than 90 per cent passing through a ¼-in. square-hole sieve) except coke breeze	250 lb.[a]
Closely-sized coke free of coke breeze	125 lb.
Coke breeze (all passing a ½- or ¾-in. square-hole sieve)	125 lb.

to read as follows:

Minimum Weights of Gross Samples of Coke

Run-of-oven, Blast-furnace, Foundry, Water-gas, and any coke containing a range of size of pieces made from uncrushed or coarsely crushed coal,[b] except coke breeze	500 lb.[a]
Run-of-oven, Blast-furnace, Foundry, Water-gas, and any coke containing a range of size of pieces made from crushed coal[c], except coke breeze	250 lb.[a]
Closely-sized coke made from uncrushed or coarsely crushed coal[b] free of coke breeze	250 lb.[a]
Closely-sized coke made from crushed coal[c] free of coke breeze	125 lb.[a]
Coke breeze (all passing a ½ or ¾-in. square-hole sieve)	125 lb.

[a] In case the pulverization of the coal is not known, take quantities designated for coke made from uncrushed or coarsely crushed coal.

[b] More than 10 per cent on a ¼-in. square-hole sieve.

[c] Not less than 90 per cent passing through a ¼-in. square-hole sieve.

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[1] See pp. 854 and 857.—ED.

[2] See p. 863.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 715 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 509.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 42 members; 41 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not" Voting"
I. PROPOSED TENTATIVE STANDARDS			
Tentative Definitions of the Terms Gross Calorific Value and Net Calorific Value of Fuels........	31	1	9
Method of Test for Grindability of Coal by Ball-Mill Method........	31	3	7
Method of Test for Grindability of Coal by Hardgrove-Machine Method........	29	3	9
Method of Test for Screen Analysis of Coal........	32	2	7
II. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Method of Sampling Coke for Analysis (D 346 – 33 T), as revised........	35	0	6

This report has been submitted to letter ballot of the committee which consists of 42 members; 41 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

W. A. SELVIG,
Secretary.

H. C. PORTER,
Vice-Chairman.

REPORT OF SECTIONAL COMMITTEE

ON

CLASSIFICATION OF COALS

A.S.A. PROJECT: M 20

The Sectional Committee on Classification of Coals, functioning under the procedure of the American Standards Association, held two meetings within the year: the annual meeting at the time of the American Institute of Mining and Metallurgical Engineers' meeting in New York City, on February 20, 1935, and a special meeting at the U. S. Bureau of Mines in Pittsburgh, Pa., on April 1, 1935.

The technical committees and their subcommittees held two group meetings: one at State College, Pa., on October 17 and 18, 1934, and the other in New York City, on February 19 and 20, 1935. Mr. John F. Barkley, Fuel Engineer of the U. S. Bureau of Mines, was elected a member of the sectional committee and of the Technical Committee on Coal Classification *vice* C. P. White, resigned; John D. Battle, who has succeeded C. B. Huntress as Executive Secretary of the National Coal Association, has been made Secretary of the sectional committee and executive committee *vice* Mr. Huntress; and T. W. Harris, Jr., has been elected to the executive committee *vice* W. H. Cunningham, who has resigned on account of retiring from the coal business.

Careful consideration was given during the past year to all criticisms and suggestions received on the tentative specifications for the classification of coals by rank and by grade. No objections were received to the grade specifications, but the New River Coal Operators' Association protested against the nomenclature and boundary lines of the low and medium volatile groups in the bituminous class of coals. Open meetings were held at the two stated meetings of the technical committees. The subject was discussed from the viewpoints of both consumer and producer and as a result the sectional committee decided to make no change in nomenclature and only one change in boundary lines of groups, namely, the change of the boundary line between medium and low volatile bituminous coal from 77 to 78 per cent dry mineral-matter-free fixed carbon. With this change, the specifications for classification of coal by rank and by grade will continue as tentative for another year.

ACTIVITIES OF TECHNICAL COMMITTEES

Technical Committee on Coal Classification (H. J. Rose, chairman).—This committee continued active work during the year through its various subcommittees:

Subcommittee II on Origin and Composition of Coal and Methods of Analysis (A. C. Fieldner, chairman), has cooperated with the Society's Committee D-5 on Coal and Coke and with other agencies on the development of standard methods for determining the slacking index, true mineral matter,[1,2,3,4] friability, grindability,[5] agglutinating[6] and agglomerating[7] values and the coke and by-product making properties of coals.[8,9,10,11] Many of these test methods are now available for use, having been published as indicated in the references given.

The classification of coal according to type, that is, by varieties such as bright, splint, cannel and boghead, is now being studied by the subcommittee.

Subcommittee V on Boundary Lines for Coal Classification (W. A. Selvig, chairman) gave extended consideration to the question of revising the boundary line between the low and medium volatile groups of bituminous coal in the Tentative Specifications for Classification of Coals by Rank (D 388 - 34 T). A statistical study was made of the analyses of low and medium-volatile coals from the various fields of the United States, and of the relation of the percentage of volatile matter to the industrial and

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[1] Contributions to the Study of Coal. L. C. McCabe, D. R. Mitchell, and G. H. **Cady**, "Banded Ingredients of No. 6 Coal and Their Heating Values as Related to Washability **Characteristics**" and "Preliminary Report on Unit Coal-Specific Gravity Curves of Illinois Coals," Illinois State **Geological** Survey *Report of Investigations No. 34* (1934).

[2] Contributions to the Study of Coal. Gilbert Thiessen, "A Proposed **Simplification** of the Parr Unit **Coal Formula**," Illinois State Geological Survey ***Report of Investigations No. 32***, **pp.** 7–25 (1934); Gilbert Thiessen, "Ash-to-Mineral Matter Correction in Coal Analyses," *ibid.*, pp. 27–39; G. H. Cady and O. W. Rees, "Unit Coal as a Basis of Coal Standardization as Applied to Illinois Coals," ***ibid.***, **pp.** 41–55; Gilbert Thiessen and F. H. Reed, "Studies of the Graphical Method of Calculating Pure Coal **Calorific** Value," ***ibid.***, pp. 57–99.

[3] C. G. Ball and G. H. Cady, "Evaluation of Ash Correction Formulae Based on Petrographic Analyses of Mineral Matter in Coal," *Economic Geology*, Vol. 30, **pp.** 72–88 (1935).

[4] A. W. Gauger, E. P. Barrett and F. J. Williams, "Mineral Matter in Coal.—A Preliminary Report," ***Transactions***, Am. Inst. Mining and Metallurgical Engrs., Vol. 108, Coal Division, **pp.** 226–236 (1934).

[5] H. F. Yancey, O. L. **Furse** and R. A. Blackburn, "Estimation of the Grindability of Coal," ***Transactions***, **Am.** Inst. Mining and Metallurgical Engrs., Vol. 108, Coal Division, **pp.** 267–294 (1934).

[6] **Proposed** Method of Test for Agglutinating Value of Coal, ***Proceedings***, Am. Soc. Testing **Mats.**, Vol. 34, **Part I, pp.** 457–462 (1934).

[7] **R. E.** Gilmore, G. P. Connell and J. H. H. Nicolls, "Agglomerating and Agglutinating **Tests** for Classifying Weakly Caking Coals," ***Transactions***, Am. Inst. Mining and Metallurgical Engrs., Vol. 108, Coal Division, pp. 255–266 (1934).

[8] B. Juettner and H. C. Howard, "Pyrolysis of Coal. Thermal Decomposition and Distillation of a Coal in High Vacuum," ***Industrial and Engineering Chemistry***, Vol. 26, **pp. 1115–1118 (1934).**

[9] A. C. Fieldner and J. D. Davis, "Gas-, Coke-, and By-Product **Making Properties** of American Coals and **Their** Determination," U. S. Bureau of Mines *Monograph No. 5* **(1934).**

[10] W. A. Selvig and W. H. Ode, "Determination of **Gas, Coke, and By-Products** of Coal. Evaluation of **Laboratory** Assay Tests," ***Industrial and Engineering Chemistry***, Analytical Edition, Vol. 7, pp. 88–93 (1935).

[11] G. C. **Sprunk** and Reinhardt Thiessen, "Relation of Microscopic Composition of Coal to Chemical **Coking** and **By-Product Properties**," ***Industrial and Engineering Chemistry***, Vol. 27, **pp.** 446–451 (1935).

domestic uses of the coal. As a result of this work and after consultation with a number of coal technologists, the subcommittee recommended that the present boundary line between low and medium volatile bituminous coal be changed from 77 to 78 per cent fixed carbon. This recommendation was adopted at the New York meeting of the technical committee and referred to letter ballot of the committee which consists of 32 members: 32 members returned their ballots, of whom 31 voted affirmatively and 1 negatively.

Subcommittee VI on Correlation of Scientific Classification with Use Classification of Coals (T. W. Harris, Jr., chairman) is developing a series of charts showing the various uses of coal and the factors to be considered in the selection of coal for these uses.

Subcommittee VII on Defining Coal Sizes and Friability (J. D. Doherty, chairman) has developed a method for determining screen sizes of bituminous coal. The method has been approved for recommendation for publication as tentative by Committee D-5 on Coal and Coke, and work is being continued on developing a standard method for describing the size-range of any sample of coal, and in devising a chart for the presentation of screen-test data.

Technical Committee on Nomenclature (E. A. Holbrook, chairman).—This committee held three meetings during the year, the first at State College, Pa., October 18, 1934; the second in Pittsburgh, Pa., December 22, 1934; and the third in New York City, February 20, 1935. At the State College meeting a protest was received from the New River Coal Operators' Association against the use of the term "medium volatile" for designating the group of coals ranging from 69 to 77 per cent fixed carbon in the bituminous class. The representatives of this association asked that the term medium volatile be dropped in favor of low volatile, or that noncommittal letters or symbols be used in place of the descriptive terms, low, medium and high.

The committee gave careful consideration to all of the arguments presented and concluded that no new evidence had been presented which would justify any change in the present descriptive nomenclature for the present boundary lines.

RECOMMENDATIONS AFFECTING STANDARDS

Proposed Revision of Tentative Specifications for Classification of Coals by Rank (D 388 - 34 T).[1]—Under Section 3 (*a*), Table I, Classification of Coals by Rank, in the column headed "Limits of Fixed Carbon or B.t.u. Mineral-Matter-Free Basis," Class II, groups 1 and 2, change to read as follows by the addition of the italicized numbers and the omission of those in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 834 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 500.

Dry F. C., [77] *78* per cent or more and less than 86 per cent (Dry V. M., [23] *22* per cent or less and more than 14 per cent).

Dry F. C., 69 per cent or more and less than [77] *78* per cent (Dry V. M., 31 per cent or less and more than [23] *22* per cent).

The above recommendation has been submitted to letter ballot of the committee which consists of 28 members; 26 members returned their ballots, of whom 25 have voted affirmatively, and 1 negatively.

This report has been submitted to letter ballot of the committee, which consists of 28 members; 26 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

J. D. BATTLE,
Secretary.

REPORT OF COMMITTEE D-7
ON
TIMBER

Committee D-7 on Timber, through its subcommittees, reports the following activities:

Subcommittee I on Specifications for Timber (C. E. Paul, chairman).—In its report appended hereto this subcommittee is presenting a revision of the Tentative Specifications for Timber Piles (D 25 – 34 T) and is also submitting as information a proposed revision of the Standard Specifications for Structural Wood Joist and Planks, Beams and Stringers, and Posts and Timbers (D 245 – 33).

Subcommittee VI on Timber Preservatives (S. R. Church, chairman).—This subcommittee recommends the adoption as standard of the Tentative Specifications for Creosote (D 390 – 34 T)[1] and the Tentative Specifications for Creosote Coal Tar Solution (D 391 – 34 T).[1] No criticism has been received by the subcommittee on these tentative specifications during the past year. As has been previously pointed out, the adoption of these specifications as standard will result in uniform standards for these materials with specifications adopted by the American Railway Engineering Association and the American Wood Preservers' Association.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 24 members; 22 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD.			
Specifications for Creosote (D 390 – 34 T)	17	1	4
Specifications for Creosote Coal Tar Solution (D 391 – 34 T)	17	1	4
II. PROPOSED REVISION OF TENTATIVE STANDARD.			
Specifications for Timber Piles (D 25 – 30 T)	21	0	1

This report has been submitted to letter ballot of the committee which consists of 24 members; 22 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. A. NEWLIN,
Secretary.

HERMANN VON SCHRENK,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 843, 845 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 515, 517.

REPORT OF SUBCOMMITTEE I ON SPECIFICATIONS FOR TIMBER

Subcommittee I on Specifications for Timber completed during the year a revision of its Tentative Specifications for Timber Piles (D 25 - 34 T)[1] which involves principally improvements in form and arrangement. The basic provisions are the same as formerly, but the specifications have been condensed without sacrificing clearness. Comparative sizes in each of the three classes of piles have been combined in a single table, with appropriate headings explaining the difference in classification as to size and quality. The subcommittee recommends the acceptance of the revised specifications as appended hereto[2] and since these are important specifications, and as the new arrangement is considerably different from the one presented to the Society last year, the subcommittee proposes that they be continued as tentative during the coming year.

The subcommittee has also given consideration to the possibility of a revision of the Standard Specifications for Structural Wood Joist and Plank, Beams and Stringers, and Posts and Timbers (D 245 - 33).[3] Experience of several years has indicated that these timber specifications are possibly too complicated to permit of ready use in specifying and purchasing structural timber. It was recognized by the committee, at the time of the presentation and adoption of the present standard rules, that the code form in which they now appear in the Book of A.S.T.M. Standards[3] would probably have to be revised sooner or later.

During the past year, much study has been given to these standard rules both by this committee, as well as the committees of the American Railway Engineering Association and the American Association of State Highway Officials. As a result, a simplified form for writing specifications for structural grades of lumber and timber was adopted. This form was presented to the American Railway Engineering Association in March of this year as information.

The new method of writing the rules does not in any way change the principles underlying the Standard Specifications for Structural Timbers as they appear in the Book of A.S.T.M. Standards of the American Society for Testing Materials or in the Manual of the American Railway Engineering Association. The new method represents one of rearrangement and, particularly, the substitution of stress values for the grade names now in the Book of Standards. For instance, instead of calling one of the grades of Douglas fir or Southern pine "Dense Select Structural Beams and Stringers," it is now proposed to call this grade "1800 lb. *f* Structural Beams and Stringers." Thus, this method provides structural grades designated in terms of the requirements of design and conforms to practical commercial manufacturing conditions.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 847 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 519.

[2] See p. 868.—Ed.

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 347.

The stress values assigned to the different grades are those for continuously dry location and, except for the two grades of Inland Empire Douglas fir and three grades of larch, may be obtained by following the procedure outlined, using the basic stress and procedure as given in a report of the U. S. Forest Products Laboratory, U. S. Department of Agriculture *Miscellaneous Publication No. 185*, entitled "Guide to the Grading of Structural Timbers and the Determination of Working Stresses," February, 1934.

This subcommittee, believing the suggested modification in the present grading rules for structural grades of lumber and timbers will tend to simplify them and lead to a more extended use, this year submits for publication as information a Proposed Revision of the Standard Specifications for Structural Wood Joist and Plank, Beams and Stringers, and Posts and Timbers (D 245 – 33), as appearing in the Appendix. In so doing, attention is called to the fact that these new rules will in every case consist of two parts: first, clauses which will apply to all stress-grades; and second, actual stress-grades for joist and plank, beams and stringers, and posts and timbers.

Respectfully submitted on behalf of the subcommittee,

C. E. PAUL,
Chairman.

APPENDIX

PROPOSED REVISION OF STANDARD SPECIFICATIONS FOR STRUCTURAL WOOD, JOIST AND PLANK, BEAMS AND STRINGERS, AND POSTS AND TIMBERS (A.S.T.M. DESIGNATION: D 245 – 33)[1]

GENERAL REQUIREMENTS

Applying to All Stress-Grades and Items

Manufacture

1. All material shall be well-manufactured.

Quality of Wood

2. No piece of exceptionally light weight is permitted.

Decay

3. Only pieces consisting of sound wood, free from any form of decay are acceptable, unless otherwise specified.

Slope of Grain

4. Slope of grain shall be measured over a distance sufficiently great to determine the general slope disregarding slight local deviations. Within the middle half of length of piece, slope of grain shall not be steeper than specified.

Holes

5. Knot holes and holes from causes other than knots are measured and limited as provided for knots.

Cluster Knots

6. Cluster knots and knots in groups are not permitted.

Knots in Joist and Plank

7. (*a*) *Knots on Narrow Faces.*—Size of knot on a narrow face is taken as width between lines enclosing knot and parallel to edges of piece. The only knots measured on narrow faces, except spike knots which cross the corners of side-cut pieces, are those that do not show on wide faces.

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[1] This is a proposed revision of an existing standard and is published as information only. Suggestions for revision are solicited and should be addressed to the Headquarters of the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-7 on Timber. The specifications appear in their present form in the 1933 Book of A.S.T.M. Standards, Part II, p. 347.

(*b*) *Knots on Wide Faces.*—Size of knot on a wide face is the average of its largest and smallest diameters. A spike knot which crosses a corner of a side-cut piece and contains the intersection of the adjacent faces, or which extends entirely across a face of a piece, shall be measured only on its end or ends, between lines parallel to the edges of the piece.

(*c*) *Permissible Increase in Knot Sizes.*—Size of knots on narrow faces and at edges of wide faces may increase proportionately from size permitted in middle third of length to twice that size at ends of piece. Size of knots on wide faces may increase proportionately from size permitted at edge to size permitted along center line.

(*d*) *Sum of Knots.*—Sum of sizes of all knots within middle half of length of any face, measured as specified by Paragraph (*a*) or (*b*) for the face under consideration, shall not exceed four and one-half times the size of largest knot allowed on that face.

Knots in Beams and Stringers

8. (*a*) *Knots on Narrow Faces.*—Size of knot on a narrow face is taken as width between lines enclosing knot and parallel to edges of piece except that when a knot on a narrow face extends into the adjacent one-fourth of the width of a wide face its least dimension is taken as its size.

(*b*) *Knots on Wide Faces.*—Size of knot on a wide face is its smallest diameter. Knots at edges of wide faces are limited to same sizes as on narrow faces but are measured according to this paragraph.

(*c*) *Permissible Increase in Knot Size.*—Size of knots on narrow faces and at edges of wide faces may increase proportionately from size permitted in middle third of length to twice that size at ends of piece, except that size of no knot shall exceed size permitted along center line of wide face. Size of knots on wide faces may increase proportionately from size permitted at edge to size permitted along center line.

(*d*) *Sum of Knots.*—Sum of sizes of all knots within middle half of length of any face, measured as specified by Paragraph (*a*) or (*b*) for the face under consideration, shall not exceed four times the size of largest knot allowed on that face.

Knots in Posts and Timbers

9. (*a*) *Knots on Either Face.*—Size of a knot is half the sum of its largest and smallest diameters. A spike knot which crosses a corner of a side-cut piece and contains the intersection of the adjacent faces, or which extends entirely across a face of a piece, shall be measured only on its end or ends, between lines parallel to the edges of the piece.

(*b*) *Sum of Knots.*—Sum of sizes of all knots in any 6 in. of the length of piece, measured as specified by Paragraph (*a*), is not permitted to exceed twice the maximum permissible size of knot. Two knots of maximum permissible size are not allowed in same 6 in. of length on any face.

Shakes, Checks, Splits in Joist and Plank and Beams and Stringers

10. (*a*) Shakes, checks and splits, where permitted in the grade specified later in these specifications, are measured at ends of piece. Only those within middle half of height are considered. (Height equals width of wide face.) Size of shake is distance between lines enclosing shake and parallel to wide faces of piece. Permissible size is determined by width of narrow face of piece.

(*b*) Checks and splits are measured and limited in same way as shakes. The following limitations apply to both ends but only within middle half of height of piece and within three times height from end. (Height equals width of wide face.) Size of checks within this portion of piece shall be taken as their estimated area, along horizontal section showing maximum area, divided by three times height of piece (Note). When checks on two parallel faces are opposite or approximately so, sum of their sizes is taken. Sum of sizes of shakes, checks, and/or splits shall not exceed permissible size of shake.

(*c*) Checks extending entirely across end within middle half of height shall not extend into piece at center of width of end a distance greater than size of allowable shake.

Shakes, Checks, Splits in Posts and Timbers

11. (*a*) Shakes, checks and splits, where permitted in the grade specified later in these specifications, are measured at the ends of the piece. Size of a shake is distance between lines enclosing shake and parallel to a pair of opposite faces.

(*b*) Checks and splits are measured and limited in the same way as shakes. Size of checks within three times width of piece from either end shall be taken as their estimated area, along the longitudinal section showing maximum area, divided by three times width of piece (Note). Sum of sizes of shakes, checks, and/or splits shall not exceed the permissible size of shake.

(*c*) Checks extending entirely across end shall not extend into piece at center of width of end, a distance greater than size of allowable shake.

NOTE.—A practical method of inspection in the field to determine the size of checks and splits under the above specification is as follows:

The size of checks within the specified portion of the piece shall be taken as the sum of seven depth measurements, one on the end and three on each side, divided by three. Each measurement shall represent the greatest depth of *any* check within the center half of the height; the measurement on the end shall be taken at the center of the width, and the three measurements on each side shall be taken at distances of one, two, and three times the height of the piece from the end in joist, plank, beams and stringers, and the width of the piece from the end in posts and timbers. Each measurement shall be determined by the penetration into the piece of a probe $\frac{1}{64}$ in. in thickness and $\frac{1}{4}$ in. in width.

OPTIONAL AND ADDITIONAL REQUIREMENTS

Applying to Stress-Grades when Heartwood or Wane, and Where Density and Close Grain Are Required

Heartwood Requirements

12. Where heartwood material is desired it shall be specified in terms of the amount or percentage of heartwood on the girth, or on each face, side or edge, measured at the point where the greatest amount of sapwood occurs.

For all timber to be pressure treated there shall be no heartwood requirement and the amount of sapwood shall not be limited.

Wane

13. Where wane is not desired, the specifications should state "Square Edge."

Density (where required)

14. (*a*) *Dense Douglas Fir or Larch.*—Shall average on either one end or the other of each piece not less than six annual rings per inch in Douglas Fir, or eight annual rings per inch in Larch, and, in addition, one-third or more summerwood (the dark portion of the annual ring) measured over 3 in. on a line at a right angle to the annual rings, located as described below. The contrast in color between summerwood and springwood shall be distinct.

Coarse-grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

In boxed-heart pieces the line shall run from the pith to the corner farthest from the pith except, when the line is not representative, it shall be shifted sufficiently to present a fair average but the distance from the pith to the beginning of the 3-in. portion of the line shall not be changed. When the least dimension is 6 in. or less, the 3-in. portion of the line shall begin at a distance of 1 in. from the pith. When the least dimension is more than 6 in., the 3-in. portion of the line shall begin at a distance from the pith equal to one-fourth the least dimension of the piece.

In side-cut pieces (pith not present) the center of the 3-in. portion of the line shall be at the center of the end of the piece.

If a 3-in. portion of the line cannot be obtained, the measurement shall be made over as much of a 3-in. portion as is available.

In case of disagreement, two radial lines shall be chosen and the summerwood and number of rings shall be taken as the average on these lines.

(*b*) *Dense Longleaf or Shortleaf Yellow Pine.*—Shall average on either one end or the other of each piece not less than six annual rings per inch, and, in addition, one-third or more summerwood (the darker, harder portion of the annual ring), measured over the third, fourth, and fifth inches of a radial line from the pith. The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood.

Coarse-grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

The radial line shall be representative of the average growth of the cross section. In case of disagreement, two radial lines shall be chosen, and the number of rings per inch and percentage of summerwood shall be taken as the average determined on these lines.

In boxed-heart pieces the measurement shall be made over the third, fourth, and fifth inches from the pith along the radial line.

In material containing the pith, but not a 5-in. radial line, which is less than 2 by 8 in. in section or less than 8 in. in width, that does not show over 16 sq. in. on the cross section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-in. radial line, the inspection shall apply to the three inches farthest from the pith.

In cases where timbers do not contain the pith and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 in. on an approximate radial line beginning at the edge nearest the pith in timbers over 3 in. in thickness and on the second inch nearest the pith in timbers 3 in. or less in thickness.

Close Grain (where required)

15. *Close-Grained Douglas Fir, or Larch, or Redwood.*—Shall average on either one end or the other of each piece not less than six nor more than twenty annual rings per inch in Douglas fir, or not less than eight nor more than thirty annual rings per inch in larch, or not less than ten nor more than thirty-five annual rings per inch in redwood, measured over 3 in. on a line at right angle to the annual rings located as described below.

In boxed-heart pieces the line shall run from the pith to the corner farthest from the pith except, when the line is not representative, it shall be shifted sufficiently to present a fair average but the distance from the pith to the beginning of the 3-in. portion of the line shall not be changed. When the least dimension is 6 in. or less, the 3-in. portion of the line shall begin at a distance of 1 in. from the pith. When the least dimension is more than 6 in., the 3-in. portion of the line shall begin at a distance from the pith equal to one-fourth the least dimension of the piece.

In side-cut pieces (pith not present) the center of the 3-in. portion of the line shall be at the center of the end of the piece.

If a 3-in. portion of the line cannot be obtained, the measurement shall be made over as much of a 3-in. portion as is available.

In case of disagreement, two radial lines shall be chosen and the number of rings shall be taken as the average on these lines.

Pieces of Douglas fir averaging five rings or more than twenty shall be accepted if containing one-third or more summerwood.

STRESS-GRADES

I. JOIST AND PLANK

f = Extreme fiber stress in bending in pounds per square inch.

1800 lb. *f* Structural Joist and Plank

DENSE DOUGLAS FIR (COAST REGION)
DENSE DOUGLAS FIR (INLAND)
DENSE LONGLEAF SOUTHERN PINE
DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	⅝ in.	On Narrow Face	......
3	1 in.		......
4	1¼ in.		......
4	¾ in.	At Edge of Wide Face	1¼ in.
6	1 in.		1⅞ in.
8	1⅜ in.		2½ in.
10	1¾ in.		3¼ in.
12	2⅛ in.		3⅞ in.
14	2¼ in.		4⅛ in.
16	2½ in.		4½ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
120 lb. Shear Grade (Fir)	1/6	¼
120 lb. Shear Grade (Pine)	3/16	⅜
Wane	1/6 Width of any face	

DENSE LARCH

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	½ in.	On Narrow Face	......
3	¾ in.		......
4	1 in.		......
4	½ in.	At Edge of Wide Face	1 in.
6	⅞ in.		1½ in.
8	1⅛ in.		2 in.
10	1⅜ in.		2⅝ in.
12	1¾ in.		3⅛ in.
14	1⅞ in.		3⅜ in.
16	2 in.		3⅝ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
120 lb. Shear Grade	⅜	3/16
Wane	1/6 Width of any face	

1600 lb. *f* Structural Joist and Plank

CLOSE-GRAINED DOUGLAS FIR (COAST REGION)

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{5}{8}$ in.	On Narrow Face	......
3	1 in.		......
4	$1\frac{1}{4}$ in.		......
4	$\frac{3}{4}$ in.	At Edge of Wide Face	$1\frac{1}{4}$ in.
6	1 in.		$1\frac{7}{8}$ in.
8	$1\frac{3}{8}$ in.		$2\frac{1}{2}$ in.
10	$1\frac{3}{4}$ in.		$3\frac{1}{4}$ in.
12	$2\frac{1}{8}$ in.		$3\frac{7}{8}$ in.
14	$2\frac{1}{4}$ in.		$4\frac{1}{8}$ in.
16	$2\frac{1}{2}$ in.		$4\frac{1}{2}$ in.

	WIDTH OF NARROW FACE When Green	When Seasoned
Shakes, Checks, Splits:		
100 lb. Shear Grade	$\frac{1}{6}$	$\frac{1}{4}$
Wane	$\frac{1}{6}$ Width of any face	

CLOSE-GRAINED DOUFLAS FIR (INLAND)
CLOSE-GRAINED LARCH

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{1}{2}$ in.	On Narrow Face	......
3	$\frac{7}{8}$ in.		......
4	$1\frac{1}{8}$ in.		......
4	$\frac{5}{8}$ in.	At Edge of Wide Face	$1\frac{1}{8}$ in.
6	$\frac{7}{8}$ in.		$1\frac{5}{8}$ in.
8	$1\frac{1}{4}$ in.		$2\frac{1}{4}$ in.
10	$1\frac{1}{2}$ in.		$2\frac{3}{4}$ in.
12	$1\frac{3}{4}$ in.		$3\frac{3}{8}$ in.
14	2 in.		$3\frac{5}{8}$ in.
16	$2\frac{1}{8}$ in.		$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE When Green	When Seasoned
Shakes, Checks, Splits:		
100 lb. Shear Grade (Larch)	$\frac{1}{4}$	$\frac{1}{3}$
80 lb. Shear Grade (Fir)	$\frac{1}{3}$	$\frac{4}{10}$
Wane	$\frac{1}{6}$ Width of any face	

DENSE LONGLEAF SOUTHERN PINE
DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{3}{4}$ in.	On Narrow Face	......
3	$1\frac{1}{8}$ in.		......
4	$1\frac{1}{2}$ in.		......
4	$\frac{7}{8}$ in.	At Edge of Wide Face	$1\frac{1}{2}$ in.
6	$1\frac{1}{4}$ in.		$2\frac{1}{4}$ in.
8	$1\frac{5}{8}$ in.		3 in.
10	$2\frac{1}{8}$ in.		$3\frac{3}{4}$ in.
12	$2\frac{1}{2}$ in.		$4\frac{1}{2}$ in.
14	$2\frac{3}{4}$ in.		$4\frac{7}{8}$ in.
16	$2\frac{7}{8}$ in.		$5\frac{1}{8}$ in.

	WIDTH OF NARROW FACE When Green	When Seasoned
Shakes, Checks, Splits:		
120 lb. Shear Grade	$\frac{3}{10}$	$\frac{3}{8}$
Wane	$\frac{1}{8}$ Width of any face	

1600 lb. *f*. Structural Joist and Plank (*Continued*)

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 16.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{3}{8}$ in.	On	......
3	$\frac{5}{8}$ in.	Narrow	......
4	$\frac{7}{8}$ in.	Face	......
4	$\frac{3}{8}$ in.		$\frac{7}{8}$ in.
6	$\frac{5}{8}$ in.	At	$1\frac{1}{4}$ in.
8	$\frac{7}{8}$ in.	Edge	$1\frac{3}{4}$ in.
10	$1\frac{1}{8}$ in.	of	$2\frac{1}{8}$ in.
12	$1\frac{1}{4}$ in.	Wide	$2\frac{1}{2}$ in.
14	$1\frac{3}{8}$ in.	Face	$2\frac{3}{4}$ in.
16	$1\frac{1}{2}$ in.		3 in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
80 lb. Shear Grade	$\frac{1}{7}$	$\frac{2}{9}$
Wane	$\frac{1}{8}$ Width of any face	

1400 lb. *f* Structural Joist and Plank

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 14.

Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{5}{8}$ in.	On	......
3	$\frac{7}{8}$ in.	Narrow	......
4	$1\frac{1}{8}$ in.	Face	......
4	$\frac{5}{8}$ in.		$1\frac{1}{8}$ in.
6	1 in.	At	$1\frac{3}{4}$ in.
8	$1\frac{1}{4}$ in.	Edge	$2\frac{3}{8}$ in.
10	$1\frac{5}{8}$ in.	of	$2\frac{7}{8}$ in.
12	$1\frac{7}{8}$ in.	Wide	$3\frac{1}{2}$ in.
14	2 in.	Face	$3\frac{3}{4}$ in.
16	$2\frac{1}{4}$ in.		$4\frac{1}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
120 lb. Shear Grade	$\frac{1}{10}$	$\frac{1}{5}$
Wane	$\frac{1}{6}$ Width of any face	

OAK

Slope of Grain.—1 in 12.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{5}{8}$ in.	On	......
3	1 in.	Narrow	......
4	$1\frac{3}{8}$ in.	Face	......
4	$\frac{3}{4}$ in.		$1\frac{1}{4}$ in.
6	$1\frac{1}{8}$ in.	At	2 in.
8	$1\frac{1}{2}$ in.	Edge	$2\frac{5}{8}$ in.
10	$1\frac{7}{8}$ in.	of	$3\frac{1}{4}$ in.
12	$2\frac{1}{4}$ in.	Wide	4 in.
14	$2\frac{3}{8}$ in.	Face	$4\frac{1}{4}$ in.
16	$2\frac{1}{2}$ in.		$4\frac{5}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
120 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{6}$ Width of any face	

1400 lb. *f* Structural Joist and Plank (*Continued*)

DENSE LONGLEAF SOUTHERN PINE

Slope of Grain.—1 in 10.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{7}{8}$ in.	On Narrow Face	......
3	$1\frac{1}{4}$ in.		......
4	$1\frac{3}{4}$ in.		......
4	1 in.	At Edge of Wide Face	$1\frac{3}{4}$ in.
6	$1\frac{1}{2}$ in.		$2\frac{5}{8}$ in.
8	2 in.		$3\frac{1}{2}$ in.
10	$2\frac{1}{2}$ in.		$4\frac{1}{4}$ in.
12	3 in.		$5\frac{1}{4}$ in.
14	$3\frac{1}{4}$ in.		$5\frac{5}{8}$ in.
16	$3\frac{3}{8}$ in.		6 in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	$\frac{4}{9}$
Wane	$\frac{1}{4}$ Width of any face	

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 14.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{1}{2}$ in.	On Narrow Face	......
3	$\frac{7}{8}$ in.		......
4	$1\frac{1}{8}$ in.		......
4	$\frac{5}{8}$ in.	At Edge of Wide Face	$1\frac{1}{8}$ in.
6	$\frac{7}{8}$ in.		$1\frac{5}{8}$ in.
8	$1\frac{1}{4}$ in.		$2\frac{1}{4}$ in.
10	$1\frac{1}{2}$ in.		$2\frac{7}{8}$ in.
12	$1\frac{7}{8}$ in.		$3\frac{3}{8}$ in.
14	2 in.		$3\frac{5}{8}$ in.
16	$2\frac{1}{8}$ in.		$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
80 lb. Shear Grade	$\frac{1}{7}$	$\frac{2}{9}$
Wane	$\frac{1}{6}$ Width of any face	

1200 lb. *f* Structural Joist and Plank

PORT ORFORD CEDAR

Slope of Grain.—1 in 14.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{1}{2}$ in.	On Narrow Face	......
3	$\frac{7}{8}$ in.		......
4	$1\frac{1}{8}$ in.		......
4	$\frac{5}{8}$ in.	At Edge of Wide Face	$1\frac{1}{8}$ in.
6	$\frac{7}{8}$ in.		$1\frac{5}{8}$ in.
8	$1\frac{1}{4}$ in.		$2\frac{1}{4}$ in.
10	$1\frac{1}{2}$ in.		$2\frac{7}{8}$ in.
12	$1\frac{7}{8}$ in.		$3\frac{3}{8}$ in.
14	2 in.		$3\frac{5}{8}$ in.
16	$2\frac{1}{8}$ in.		$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{1}{6}$	$\frac{1}{4}$
Wane	$\frac{1}{6}$ Width of any face	

1200 lb. *f* Structural Joist and Plank (*Continued*)

DOUGLAS FIR (COAST REGION)

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	⅞ in.	On Narrow Face	......
3	1¼ in.		......
4	1¾ in.		......
4	1 in.	At Edge of Wide Face	1¾ in.
6	1½ in.		2⅝ in.
8	2 in.		3½ in.
10	2½ in.		4¼ in.
12	3 in.		5¼ in.
14	3¼ in.		5⅝ in.
16	3⅜ in.		6 in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	⅙	¼
Wane	¼ Width of any face	

DOUGLAS FIR (INLAND)
LARCH

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	¾ in.	On Narrow Face	......
3	1⅛ in.		......
4	1½ in.		......
4	⅞ in.	At Edge of Wide Face	1½ in.
6	1¼ in.		2⅜ in.
8	1¾ in.		3⅛ in.
10	2¼ in.		3⅞ in.
12	2⅝ in.		4¾ in.
14	2⅞ in.		5⅛ in.
16	3 in.		5½ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade (Larch)	¼	⅓
80 lb. Shear Grade (Fir)	⅓	$\frac{4}{10}$
Wane	⅕ Width of any face	

DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 8.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	1 in.	On Narrow Face	......
3	1½ in.		......
4	2 in.		......
4	1⅛ in.	At Edge of Wide Face	2 in.
6	1¾ in.		3 in.
8	2¼ in.		3⅞ in.
10	2⅞ in.		4⅞ in.
12	3½ in.		5⅞ in.
14	3¾ in.		6⅜ in.
16	4 in.		6⅞ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	½
Wane	¼ Width of any face	

1200 lb. *f* Structural Joist and Plank (*Continued*)

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{3}{4}$ in.	On	......
3	$1\frac{1}{8}$ in.	Narrow	......
4	$1\frac{1}{2}$ in.	Face	......
4	$\frac{7}{8}$ in.		$1\frac{3}{8}$ in.
6	$1\frac{1}{4}$ in.	At	$2\frac{1}{8}$ in.
8	$1\frac{5}{8}$ in.	Edge	$2\frac{7}{8}$ in.
10	2 in.	of	$3\frac{5}{8}$ in.
12	$2\frac{3}{8}$ in.	Wide	$4\frac{3}{8}$ in.
14	$2\frac{5}{8}$ in.	Face	$4\frac{3}{4}$ in.
16	$2\frac{3}{4}$ in.		5 in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
70 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{5}$ Width of any face	

1100 lb. *f* Structural Joist and Plank

PORT ORFORD CEDAR

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{5}{8}$ in.	On	......
3	1 in.	Narrow	......
4	$1\frac{3}{8}$ in.	Face	......
4	$\frac{3}{4}$ in.		$1\frac{1}{4}$ in.
6	$1\frac{1}{8}$ in.	At	2 in.
8	$1\frac{1}{2}$ in.	Edge	$2\frac{5}{8}$ in.
10	$1\frac{7}{8}$ in.	of	$3\frac{1}{4}$ in.
12	$2\frac{1}{4}$ in.	Wide	4 in.
14	$2\frac{3}{8}$ in.	Face	$4\frac{1}{4}$ in.
16	$2\frac{1}{2}$ in.		$4\frac{5}{8}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
80 lb. Shear Grade	$\frac{1}{3}$	$\frac{4}{10}$
Wane	$\frac{1}{6}$ Width of any face	

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 10.
Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, OR AT EDGE OF WIDE FACE, MIDDLE THIRD OF LENGTH		AT CENTER LINE OF WIDE FACE
2	$\frac{3}{4}$ in.	On	......
3	$1\frac{1}{4}$ in.	Narrow	......
4	$1\frac{5}{8}$ in.	Face	......
4	$\frac{7}{8}$ in.		$1\frac{5}{8}$ in.
6	$1\frac{3}{8}$ in.	At	$2\frac{1}{2}$ in.
8	$1\frac{7}{8}$ in.	Edge	$3\frac{1}{4}$ in.
10	$2\frac{3}{8}$ in.	of	$4\frac{1}{8}$ in.
12	$2\frac{3}{4}$ in.	Wide	5 in.
14	3 in.	Face	$5\frac{3}{8}$ in.
16	$3\frac{1}{4}$ in.		$5\frac{3}{4}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{4}$ Width of any face	

1100 lb. *f* Structural Joist and Plank (*Continued*)

Oak

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

Nominal Width of Face, in.	On Narrow Face, or at Edge of Wide Face, Middle Third of Length		At Center Line of Wide Face
2	$\frac{7}{8}$ in.	On Narrow Face	......
3	$1\frac{3}{8}$ in.		......
4	$1\frac{3}{4}$ in.		......
4	1 in.	At Edge of Wide Face	$1\frac{3}{4}$ in.
6	$1\frac{1}{2}$ in.		$2\frac{5}{8}$ in.
8	2 in.		$3\frac{1}{2}$ in.
10	$2\frac{1}{2}$ in.		$4\frac{3}{8}$ in.
12	3 in.		$5\frac{1}{4}$ in.
14	$3\frac{1}{4}$ in.		$5\frac{3}{4}$ in.
16	$3\frac{1}{2}$ in.		$6\frac{1}{8}$ in.

Shakes, Checks, Splits:	Width of Narrow Face When Green	Width of Narrow Face When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	$\frac{4}{9}$
Wane	$\frac{1}{4}$ Width of any face	

1000 lb. *f* Structural Joist and Plank

Western Red Cedar

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

Nominal Width of Face, in.	On Narrow Face, or at Edge of Wide Face, Middle Third of Length		At Center Line of Wide Face
2	$\frac{1}{2}$ in.	On Narrow Face	......
3	$\frac{7}{8}$ in.		......
4	$1\frac{1}{8}$ in.		......
4	$\frac{5}{8}$ in.	At Edge of Wide Face	$1\frac{1}{8}$ in.
6	$\frac{7}{8}$ in.		$1\frac{5}{8}$ in.
8	$1\frac{1}{4}$ in.		$2\frac{1}{4}$ in.
10	$1\frac{1}{2}$ in.		$2\frac{3}{4}$ in.
12	$1\frac{3}{4}$ in.		$3\frac{3}{8}$ in.
14	2 in.		$3\frac{5}{8}$ in.
16	$2\frac{1}{8}$ in.		$3\frac{7}{8}$ in.

Shakes, Checks, Splits:	Width of Narrow Face When Green	Width of Narrow Face When Seasoned
100 lb. Shear Grade	$\frac{1}{18}$	$\frac{1}{6}$
Wane	$\frac{1}{6}$ Width of any face	

II. STRUCTURAL BEAMS AND STRINGERS

f = Extreme fiber stress in bending in pounds per square inch.

1800 lb. *f* Structural Beams and Stringers

Dense Douglas Fir (Coast Region)
Dense Douglas Fir (Inland)
Dense Longleaf Southern Pine
Dense Shortleaf Southern Pine

Slope of Grain.—1 in 16.
Knots.—Maximum permissible size in inches:

Nominal Width of Face, in.	On Narrow Face, Middle Third of Length	At Center Line of Wide Face
5	$1\frac{1}{8}$ in.	......
6	$1\frac{3}{8}$ in.	......
8	$1\frac{5}{8}$ in.	$1\frac{7}{8}$ in.
10	$1\frac{3}{4}$ in.	$2\frac{1}{4}$ in.
12	$1\frac{7}{8}$ in.	$2\frac{5}{8}$ in.
14	$2\frac{1}{8}$ in.	$2\frac{7}{8}$ in.
16	$2\frac{1}{4}$ in.	$3\frac{1}{8}$ in.
18	......	$3\frac{3}{8}$ in.
20	......	$3\frac{1}{2}$ in.

Shakes, Checks, Splits:	Width of Narrow Face When Green	Width of Narrow Face When Seasoned
120 lb. Shear Grade (Fir)	$\frac{1}{6}$	$\frac{1}{4}$
120 lb. Shear Grade (Pine)	$\frac{3}{10}$	$\frac{3}{8}$
Wane	$\frac{1}{8}$ Width of any face	

1800 lb. *f* Structural Beams and Stringers (*Continued*)

DENSE LARCH

Slope of Grain.—1 in 18.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$\frac{3}{4}$ in.	......
6	$\frac{7}{8}$ in.	......
8	1 in.	$1\frac{1}{8}$ in.
10	$1\frac{1}{8}$ in.	$1\frac{3}{8}$ in.
12	$1\frac{1}{4}$ in.	$1\frac{3}{4}$ in.
14	$1\frac{1}{4}$ in.	$1\frac{7}{8}$ in.
16	$1\frac{3}{8}$ in.	2 in.
18	......	$2\frac{1}{8}$ in.
20	......	$2\frac{1}{4}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
120 lb. Shear Grade	$\frac{2}{9}$	$\frac{3}{10}$
Wane	$\frac{1}{8}$ Width of any face	

1600 lb. *f* Structural Beams and Stringers

CLOSE-GRAINED DOUGLAS FIR (COAST REGION)

Slope of Grain.—1 in 15.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{1}{8}$ in.	......
6	$1\frac{3}{8}$ in.	......
8	$1\frac{5}{8}$ in.	$1\frac{7}{8}$ in.
10	$1\frac{3}{4}$ in.	$2\frac{1}{4}$ in.
12	$1\frac{7}{8}$ in.	$2\frac{5}{8}$ in.
14	$2\frac{1}{8}$ in.	$2\frac{7}{8}$ in.
16	$2\frac{1}{4}$ in.	$3\frac{1}{8}$ in.
18	......	$3\frac{3}{8}$ in.
20	......	$3\frac{1}{2}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{1}{6}$	$\frac{1}{4}$
Wane	$\frac{1}{6}$ Width of any face	

CLOSE-GRAINED DOUGLAS FIR (INLAND)

CLOSE-GRAINED LARCH

Slope of Grain.—1 in 18.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$\frac{3}{4}$ in.	......
6	1 in.	......
8	$1\frac{1}{8}$ in.	$1\frac{3}{8}$ in.
10	$1\frac{1}{4}$ in.	$1\frac{5}{8}$ in.
12	$1\frac{3}{8}$ in.	2 in.
14	$1\frac{1}{2}$ in.	$2\frac{1}{8}$ in.
16	$1\frac{5}{8}$ in.	$2\frac{1}{4}$ in.
18	......	$2\frac{3}{8}$ in.
20	......	$2\frac{1}{2}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade (Larch)	$\frac{1}{4}$	$\frac{1}{3}$
80 lb. Shear Grade (Fir)	$\frac{1}{3}$	$\frac{4}{10}$
Wane	$\frac{1}{8}$ Width of any face	

1600 lb. *f* Structural Beams and Stringers (*Continued*)

DENSE LONGLEAF SOUTHERN PINE
DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	1½ in.	......
6	1⅞ in.	......
8	2⅛ in.	2½ in.
10	2⅜ in.	3⅛ in.
12	2⅝ in.	3¾ in.
14	2⅞ in.	4 in.
16	3 in.	4⅜ in.
18	......	4⅝ in.
20	......	4⅞ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
120 lb. Shear Grade	3⁄16	⅜

Wane ⅙ Width of any face

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 20.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	⅜ in.	......
6	⅜ in.	......
8	½ in.	½ in.
10	½ in.	⅝ in.
12	⅝ in.	¾ in.
14	⅝ in.	⅞ in.
16	¾ in.	⅞ in.
18	......	1 in.
20	......	1 in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
80 lb. Shear Grade	¼	⅖

Wane ⅒ Width of any face

1400 lb. *f* Structural Beams and Stringers

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 16.
Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	1 in.	......
6	1⅛ in.	......
8	1⅜ in.	1½ in.
10	1½ in.	1⅞ in.
12	1⅝ in.	2¼ in.
14	1¾ in.	2½ in.
16	1⅞ in.	2⅝ in.
18	......	2⅞ in.
20	......	3 in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
120 lb. Shear Grade	⅒	⅕

Wane ⅛ Width of any face

1400 lb. *f* Structural Beams and Stringers (*Continued*)

OAK

Slope of Grain.—1 in 15.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{1}{4}$ in.	......
6	$1\frac{1}{2}$ in.	......
8	$1\frac{3}{4}$ in.	2 in
10	2 in.	$2\frac{1}{2}$ in.
12	$2\frac{1}{8}$ in.	3 in.
14	$2\frac{1}{4}$ in.	$3\frac{1}{4}$ in.
16	$2\frac{1}{2}$ in.	$3\frac{1}{2}$ in.
18	......	$3\frac{3}{4}$ in.
20	......	$3\frac{7}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
120 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{6}$ Width of any face	

DENSE LONGLEAF SOUTHERN PINE

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	2 in.	......
6	$2\frac{3}{8}$ in.	......
8	$2\frac{3}{4}$ in.	$3\frac{1}{4}$ in.
10	$3\frac{1}{8}$ in.	4 in.
12	$3\frac{3}{8}$ in.	$4\frac{7}{8}$ in.
14	$3\frac{5}{8}$ in.	$5\frac{1}{4}$ in.
16	4 in.	$5\frac{5}{8}$ in.
18	......	$5\frac{7}{8}$ in.
20	......	$6\frac{1}{4}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	$\frac{4}{9}$
Wane	$\frac{1}{4}$ Width of any face	

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 18.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$\frac{7}{8}$ in.	......
6	$1\frac{1}{8}$ in.	......
8	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.
10	$1\frac{3}{8}$ in.	$1\frac{3}{4}$ in.
12	$1\frac{1}{2}$ in.	$2\frac{1}{4}$ in.
14	$1\frac{5}{8}$ in.	$2\frac{3}{8}$ in.
16	$1\frac{3}{4}$ in.	$2\frac{1}{2}$ in.
18	......	$2\frac{3}{4}$ in.
20	......	$2\frac{3}{4}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
80 lb. Shear Grade	$\frac{1}{7}$	$\frac{2}{9}$
Wane	$\frac{1}{8}$ Width of any face	

1200 lb. *f* Structural Beams and Stringers

DOUGLAS FIR (INLAND)
LARCH

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{5}{8}$ in.	......
6	2 in.	......
8	$2\frac{1}{4}$ in.	$2\frac{5}{8}$ in.
10	$2\frac{5}{8}$ in.	$3\frac{1}{4}$ in.
12	$2\frac{7}{8}$ in.	4 in.
14	3 in.	$4\frac{1}{4}$ in.
16	$3\frac{1}{4}$ in.	$4\frac{5}{8}$ in.
18	......	$4\frac{7}{8}$ in.
20	......	$5\frac{1}{8}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade (Larch)	$\frac{1}{4}$	$\frac{1}{3}$
80 lb. Shear Grade (Fir)	$\frac{1}{3}$	$\frac{4}{10}$
Wane	$\frac{1}{6}$ Width of any face	

DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 8.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$2\frac{3}{8}$ in.	......
6	$2\frac{7}{8}$ in.	......
8	$3\frac{3}{8}$ in.	$3\frac{7}{8}$ in.
10	$3\frac{3}{4}$ in.	$4\frac{7}{8}$ in.
12	$4\frac{1}{8}$ in.	$5\frac{3}{4}$ in.
14	$4\frac{3}{8}$ in.	$6\frac{1}{4}$ in.
16	$4\frac{3}{4}$ in.	$6\frac{3}{4}$ in.
18	......	$7\frac{1}{8}$ in.
20	......	$7\frac{1}{2}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	$\frac{4}{9}$
Wane	$\frac{1}{4}$ Width of any face	

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{1}{2}$ in.	......
6	$1\frac{3}{4}$ in.	......
8	$2\frac{1}{8}$ in.	$2\frac{3}{8}$ in.
10	$2\frac{3}{8}$ in.	3 in.
12	$2\frac{5}{8}$ in.	$3\frac{5}{8}$ in.
14	$2\frac{3}{4}$ in.	$3\frac{7}{8}$ in.
16	3 in.	$4\frac{1}{4}$ in.
18	......	$4\frac{1}{2}$ in.
20	......	$4\frac{3}{4}$ in.

	WIDTH OF NARROW FACE	
Shakes, Checks, Splits:	When Green	When Seasoned
70 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{6}$ Width of any face	

1100 lb. *f* Structural Beams and Stringers

PORT ORFORD CEDAR

Slope of Grain.—1 in 15.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{1}{4}$ in.	......
6	$1\frac{1}{2}$ in.	......
8	$1\frac{3}{4}$ in.	2 in.
10	2 in.	$2\frac{1}{2}$ in.
12	$2\frac{1}{8}$ in.	3 in.
14	$2\frac{1}{4}$ in.	$3\frac{1}{4}$ in.
16	$2\frac{1}{2}$ in.	$3\frac{1}{2}$ in.
18	......	$3\frac{3}{4}$ in.
20	......	$3\frac{7}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
80 lb. Shear Grade	$\frac{1}{3}$	$\frac{4}{10}$
Wane	$\frac{1}{6}$ Width of any face	

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 12.
Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$1\frac{3}{4}$ in.	......
6	$2\frac{1}{8}$ in.	......
8	$2\frac{1}{2}$ in.	$2\frac{7}{8}$ in.
10	$2\frac{3}{4}$ in.	$3\frac{5}{8}$ in.
12	$3\frac{1}{8}$ in.	$4\frac{3}{8}$ in.
14	$3\frac{3}{8}$ in.	$4\frac{3}{4}$ in.
16	$3\frac{1}{2}$ in.	5 in.
18	......	$5\frac{3}{8}$ in.
20	......	$5\frac{5}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
100 lb. Shear Grade	$\frac{1}{4}$	$\frac{1}{3}$
Wane	$\frac{1}{5}$ Width of any face	

OAK

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	2 in.	......
6	$2\frac{1}{2}$ in.	......
8	$2\frac{7}{8}$ in.	$3\frac{1}{4}$ in.
10	$3\frac{1}{4}$ in.	$4\frac{1}{8}$ in.
12	$3\frac{1}{2}$ in.	5 in.
14	$3\frac{3}{4}$ in.	$5\frac{3}{8}$ in.
16	4 in.	$5\frac{3}{4}$ in.
18	......	6 in.
20	......	$6\frac{3}{8}$ in.

Shakes, Checks, Splits:	WIDTH OF NARROW FACE When Green	When Seasoned
100 lb. Shear Grade	$\frac{4}{10}$	$\frac{4}{9}$
Wane	$\frac{1}{4}$ Width of any face	

1000 lb. *f* Structural Beams and Stringers

WESTERN RED CEDAR

Slope of Grain.—1 in 18.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	ON NARROW FACE, MIDDLE THIRD OF LENGTH	AT CENTER LINE OF WIDE FACE
5	$\frac{3}{4}$ in.	......
6	1 in.	......
8	$1\frac{1}{8}$ in.	$1\frac{3}{8}$ in.
10	$1\frac{1}{4}$ in.	$1\frac{5}{8}$ in.
12	$1\frac{3}{8}$ in.	2 in.
14	$1\frac{1}{2}$ in.	$2\frac{1}{8}$ in.
16	$1\frac{5}{8}$ in.	$2\frac{1}{4}$ in.
18	......	$2\frac{3}{8}$ in.
20	......	$2\frac{1}{2}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits:		
100 lb. Shear Grade	$\frac{1}{8}$	$\frac{1}{6}$
Wane	$\frac{1}{8}$ Width of any face	

III. STRUCTURAL POSTS AND TIMBERS

c = Compression stress parallel to grain in pounds per square inch.

1300 lb. *c* Structural Posts and Timbers

DENSE DOUGLAS FIR (COAST REGION)
DENSE DOUGLAS FIR (INLAND)
DENSE LARCH
DENSE LONGLEAF SOUTHERN PINE
DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{4}$ in.
6	$1\frac{1}{2}$ in.
8	$1\frac{7}{8}$ in.
10	$2\frac{3}{8}$ in.
12	$2\frac{7}{8}$ in.
14	$3\frac{1}{8}$ in.
16	$3\frac{3}{8}$ in.
18	$3\frac{1}{2}$ in.
20	$3\frac{3}{4}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{8}$ Width of any face	

1200 lb. *c* Structural Posts and Timbers

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 12.
Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$\frac{7}{8}$ in.
6	$1\frac{1}{8}$ in.
8	$1\frac{1}{2}$ in.
10	$1\frac{3}{4}$ in.
12	$2\frac{1}{4}$ in.
14	$2\frac{3}{8}$ in.
16	$2\frac{1}{2}$ in.
18	$2\frac{3}{4}$ in.
20	$2\frac{3}{4}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{1}{3}$	$\frac{4}{9}$
Wane	$\frac{1}{8}$ Width of any face	

1200 lb. *c* Structural Posts and Timbers (*Continued*)

CLOSE-GRAINED DOUGLAS FIR (COAST REGION)
CLOSE-GRAINED LARCH

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{8}$ in.
6	$1\frac{3}{8}$ in.
8	$1\frac{7}{8}$ in.
10	$2\frac{3}{8}$ in.
12	$2\frac{3}{4}$ in.
14	3 in.
16	$3\frac{1}{4}$ in.
18	$3\frac{3}{8}$ in.
20	$3\frac{5}{8}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{8}$ Width of any face	

CLOSE-GRAINED DOUGLAS FIR (INLAND)

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	1 in.
6	$1\frac{1}{8}$ in.
8	$1\frac{1}{2}$ in.
10	$1\frac{7}{8}$ in.
12	$2\frac{1}{4}$ in.
14	$2\frac{1}{2}$ in.
16	$2\frac{5}{8}$ in.
18	$2\frac{7}{8}$ in.
20	3 in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{1}{3}$	$\frac{4}{9}$
Wane	$\frac{1}{8}$ Width of any face	

DENSE LONGLEAF SOUTHERN PINE
DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{2}$ in.
6	$1\frac{3}{4}$ in.
8	$2\frac{3}{8}$ in.
10	3 in.
12	$3\frac{5}{8}$ in.
14	$3\frac{7}{8}$ in.
16	$4\frac{1}{4}$ in.
18	$4\frac{1}{2}$ in.
20	$4\frac{3}{4}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{6}$ Width of any face	

1200 lb. *c* Structural Posts and Timbers (*Continued*)

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$\frac{3}{4}$ in.
6	$\frac{7}{8}$ in.
8	$1\frac{1}{4}$ in.
10	$1\frac{1}{2}$ in.
12	$1\frac{7}{8}$ in.
14	2 in.
16	$2\frac{1}{8}$ in.
18	$2\frac{1}{4}$ in.
20	$2\frac{3}{8}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{1}{3}$	$\frac{4}{9}$
Wane	$\frac{1}{8}$ Width of any face	

1100 lb. *c* Structural Posts and Timbers

DOUGLAS FIR (COAST REGION)
LARCH

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{4}$ in.
6	$1\frac{1}{2}$ in.
8	2 in.
10	$2\frac{1}{2}$ in.
12	3 in.
14	$3\frac{1}{4}$ in.
16	$3\frac{1}{2}$ in.
18	$3\frac{3}{4}$ in.
20	$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{6}$ Width of any face	

DOUGLAS FIR (INLAND)

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$\frac{3}{4}$ in.
6	$1\frac{1}{4}$ in.
8	$1\frac{5}{8}$ in.
10	$2\frac{1}{8}$ in.
12	$2\frac{3}{8}$ in.
14	$2\frac{5}{8}$ in.
16	$2\frac{7}{8}$ in.
18	3 in.
20	$3\frac{1}{8}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{3}{8}$	$\frac{4}{9}$
Wane	$\frac{1}{8}$ Width of any face	

1100 lb. *c* Structural Posts and Timbers (*Continued*)

OAK

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	7/8 in.
6	1 in.
8	1 3/8 in.
10	1 3/4 in.
12	2 1/8 in.
14	2 1/4 in.
16	2 3/8 in.
18	2 1/2 in.
20	2 5/8 in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	1/3	3/7
Wane	1/8 Width of any face	

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	1 1/8 in.
6	1 3/8 in.
8	1 3/4 in.
10	2 1/4 in.
12	2 5/8 in.
14	2 7/8 in.
16	3 1/8 in.
18	3 1/4 in.
20	3 1/2 in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	3/8	1/2
Wane	1/8 Width of any face	

1000 lb. *c* Structural Posts and Timbers

PORT ORFORD CEDAR

Slope of Grain.—1 in 14.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	7/8 in.
6	1 in.
8	1 3/8 in.
10	1 5/8 in.
12	2 in.
14	2 1/8 in.
16	2 1/4 in.
18	2 3/8 in.
20	2 1/2 in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	1/3	3/7
Wane	1/8 Width of any face	

1000 lb. *c* Structural Posts and Timbers (*Continued*)

TIDEWATER RED CYPRESS

Slope of Grain.—1 in 10.
Knots and Peck.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{5}{8}$ in.
6	$1\frac{7}{8}$ in.
8	$2\frac{1}{2}$ in.
10	$3\frac{1}{4}$ in.
12	$3\frac{3}{4}$ in.
14	4 in.
16	$4\frac{3}{8}$ in.
18	$4\frac{3}{4}$ in.
20	5 in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{4}{9}$	$\frac{5}{9}$
Wane	$\frac{1}{6}$ Width of any face	

OAK

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{4}$ in.
6	$1\frac{1}{2}$ in.
8	2 in.
10	$2\frac{1}{2}$ in.
12	3 in.
14	$3\frac{1}{4}$ in.
16	$3\frac{1}{2}$ in.
18	$3\frac{3}{4}$ in.
20	$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{6}$ Width of any face	

DENSE LONGLEAF SOUTHERN PINE

Slope of Grain.—1 in 8.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$2\frac{1}{8}$ in.
6	$2\frac{1}{2}$ in.
8	$3\frac{3}{8}$ in.
10	$4\frac{1}{8}$ in.
12	5 in.
14	$5\frac{3}{8}$ in.
16	$5\frac{3}{4}$ in.
18	$6\frac{1}{8}$ in.
20	$6\frac{3}{8}$ in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{1}{2}$	$\frac{5}{8}$
Wane	$\frac{1}{4}$ Width of any face	

1000 lb. *c* Structural Posts and Timbers (*Continued*)

CLOSE-GRAINED REDWOOD

Slope of Grain.—1 in 10.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{2}$ in.
6	$1\frac{3}{4}$ in.
8	$2\frac{3}{8}$ in.
10	$2\frac{7}{8}$ in.
12	$3\frac{1}{2}$ in.
14	$3\frac{3}{4}$ in.
16	$4\frac{1}{8}$ in.
18	$4\frac{3}{8}$ in.
20	$4\frac{5}{8}$ in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{3}{7}$	$\frac{1}{2}$
Wane	$\frac{1}{6}$ Width of any face	

900 lb. *c* Structural Posts and Timbers

PORT ORFORD CEDAR

Slope of Grain.—1 in 12.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$1\frac{1}{4}$ in.
6	$1\frac{1}{2}$ in.
8	2 in.
10	$2\frac{1}{2}$ in.
12	3 in.
14	$3\frac{1}{4}$ in.
16	$3\frac{1}{2}$ in.
18	$3\frac{3}{4}$ in.
20	$3\frac{7}{8}$ in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{4}{10}$	$\frac{1}{2}$
Wane	$\frac{1}{6}$ Width of any face	

DENSE SHORTLEAF SOUTHERN PINE

Slope of Grain.—1 in 6.
Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$2\frac{3}{8}$ in.
6	$2\frac{7}{8}$ in.
8	$3\frac{3}{4}$ in.
10	$4\frac{3}{4}$ in.
12	$5\frac{5}{8}$ in.
14	$6\frac{1}{8}$ in.
16	$6\frac{1}{2}$ in.
18	7 in.
20	$7\frac{1}{4}$ in.

	WIDTH OF NARROW FACE When Green	WIDTH OF NARROW FACE When Seasoned
Shakes, Checks, Splits	$\frac{5}{9}$	$\frac{2}{3}$
Wane	$\frac{1}{4}$ Width of any face	

800 lb. *c* Posts and Timbers

WESTERN RED CEDAR

Slope of Grain.—1 in 14.

Knots.—Maximum permissible size in inches:

NOMINAL WIDTH OF FACE, IN.	AT ANY POINT ON ANY FACE
5	$\frac{3}{4}$ in.
6	$\frac{3}{4}$ in.
8	$1\frac{1}{8}$ in.
10	$1\frac{3}{8}$ in.
12	$1\frac{3}{4}$ in.
14	$1\frac{7}{8}$ in.
16	2 in.
18	$2\frac{1}{8}$ in.
20	$2\frac{1}{4}$ in.

	WIDTH OF NARROW FACE	
	When Green	When Seasoned
Shakes, Checks, Splits	$\frac{3}{16}$	$\frac{3}{8}$
Wane	$\frac{1}{8}$ Width of any face	

See Appendix beginning on next page.

APPENDIX

The following three tables summarizing standard sizes, stress-grades and working stresses for joist and plank, beams and stringers, and posts and timbers are appended for information. They offer a valuable key to different structural grades.

TABLE I.—STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL JOIST AND PLANK.

Standard Sizes

Nominal thicknesses	2, 3 and 4 in.
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:	
2 in.	$\frac{1}{8}$ in. off
3 and 4 in.	$\frac{3}{16}$ in. off
Dressed thicknesses, S1S or S2S	$\frac{3}{8}$ in. off
Nominal widths	4 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment:	
4 and 6 in.	$\frac{3}{16}$ in. off
8 in. and wider	$\frac{1}{4}$ in. off
Dressed widths, S1E or S2E:	
4 and 6 in.	$\frac{3}{8}$ in. off
8 in. and wider	$\frac{1}{2}$ in. off

Standard Stress-Grades and Working Stresses

GRADES AND SPECIES	FIBER STRESS IN BENDING OR TENSION, LB. PER SQ. IN.	MAXIMUM HORIZONTAL SHEAR, LB.	COMPRESSION PERPENDICULAR TO GRAIN, LB.	MODULUS OF ELASTICITY, LB. PER SQ. IN.
1800 lb. *f* Dense Douglas Fir (Coast and Inland)	1800	120	380	1 600 000
1800 lb. *f* Dense Larch	1800	120	380	1 300 000
1800 lb. *f* Dense Longleaf or Dense Shortleaf Southern Pine	1800	120	380	1 600 000
1600 lb. *f* Close-Grained Douglas Fir (Coast)	1600	100	345	1 600 000
1600 lb. *f* Close-Grained Douglas Fir (Inland)	1600	80	335	1 500 000
1600 lb. *f* Close-Grained Larch	1600	100	345	1 300 000
1600 lb. *f* Dense Longleaf or Dense Shortleaf Southern Pine	1600	120	380	1 600 000
1600 lb. *f* Close-Grained Redwood	1600	80	267	1 200 000
1400 lb. *f* Tidewater Red Cypress	1400	120	300	1 200 000
1400 lb. *f* Oak	1400	120	500	1 500 000
1400 lb. *f* Dense Longleaf Southern Pine	1400	100	380	1 600 000
1400 lb. *f* Close-Grained Redwood	1400	80	267	1 200 000
1200 lb. *f* Port Orford Cedar	1200	100	250	1 200 000
1200 lb. *f* Douglas Fir (Coast)	1200	100	325	1 600 000
1200 lb. *f* Douglas Fir (Inland)	1200	80	315	1 500 000
1200 lb. *f* Larch	1200	100	325	1 300 000
1200 lb. *f* Dense Shortleaf Southern Pine	1200	100	380	1 600 000
1200 lb. *f* Close-Grained Redwood	1200	70	267	1 200 000
1100 lb. *f* Port Orford Cedar	1100	80	250	1 200 000
1100 lb. *f* Tidewater Red Cypress	1100	100	300	1 200 000
1100 lb. *f* Oak	1100	100	500	1 500 000
1000 lb. *f* Western Red Cedar	1000	100	200	1 000 000

TABLE II.—STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL BEAMS AND STRINGERS.

Standard Sizes

Nominal thicknesses	5 in. and thicker
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	$\frac{3}{16}$ in. off
8 in. and wider	$\frac{1}{4}$ in. off
Dressed thicknesses, S1S or S2S	$\frac{1}{2}$ in. off
Nominal widths	8 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment	$\frac{1}{4}$ in. off
Dressed widths, S1E or S2E	$\frac{1}{2}$ in. off

Standard Stress-Grades and Working Stresses

GRADES AND SPECIES	FIBER STRESS IN BENDING OR TENSION, LB. PER SQ. IN.	MAXIMUM HORIZONTAL SHEAR, LB.	COMPRESSION PERPENDICULAR TO GRAIN, LB.	MODULUS OF ELASTICITY, LB. PER SQ. IN.
1800 lb. *f* Dense Douglas Fir (Coast and Inland)	1800	120	380	1 600 000
1800 lb. *f* Dense Larch	1800	120	380	1 300 000
1800 lb. *f* Dense Longleaf or Dense Shortleaf Southern Pine	1800	120	380	1 600 000
1600 lb. *f* Close-Grained Douglas Fir (Coast)	1600	100	345	1 600 000
1600 lb. *f* Close-Grained Douglas Fir (Inland)	1600	80	335	1 500 000
1600 lb. *f* Close-Grained Larch	1600	100	345	1 300 000
1600 lb. *f* Dense Longleaf or Dense Shortleaf Southern Pine	1600	120	380	1 600 000
1600 lb. *f* Close-Grained Redwood	1600	80	267	1 200 000
1400 lb. *f* Tidewater Red Cypress	1400	120	300	1 200 000
1400 lb. *f* Oak	1400	120	500	1 500 000
1400 lb. *f* Dense Longleaf Southern Pine	1400	100	380	1 600 000
1400 lb. *f* Close-Grained Redwood	1400	80	267	1 200 000
1200 lb. *f* Douglas Fir (Inland)	1200	80	315	1 500 000
1200 lb. *f* Larch	1200	100	325	1 300 000
1200 lb. *f* Dense Shortleaf Southern Pine	1200	100	380	1 600 000
1200 lb. *f* Close-Grained Redwood	1200	70	267	1 200 000
1100 lb. *f* Port Orford Cedar	1100	80	250	1 200 000
1100 lb. *f* Tidewater Red Cypress	1100	100	300	1 200 000
1100 lb. *f* Oak	1100	100	500	1 500 000
1000 lb. *f* Western Red Cedar	1000	100	200	1 000 000

TABLE III.—STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL POSTS AND TIMBERS.

Standard Sizes:

Nominal thicknesses	5 in. and thicker
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	$\frac{3}{16}$ in. off
8 in. and wider	$\frac{1}{4}$ in. off
Dressed thicknesses, S1S or S2S	$\frac{1}{2}$ in. off
Nominal widths	5 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	$\frac{3}{16}$ in. off
8 in. and wider	$\frac{1}{4}$ in. off
Dressed widths, S1E or S2E	$\frac{1}{2}$ in. off

Standard Stress-Grades and Working Stresses

GRADES AND SPECIES	COMPRESSION PARALLEL TO GRAIN, SHORT COLUMNS, LB. PER SQ. IN.	
1300 lb. *c* Dense Douglas Fir (Coast and Inland)	1300	
1300 lb. *c* Dense Larch	1300	
1300 lb. *c* Dense Longleaf or Dense Shortleaf Southern Pine	1300	
1200 lb. *c* Tidewater Red Cypress	1200	
1200 lb. *c* Close-Grained Douglas Fir (Coast)	1200	For stresses in compression perpendicular to grain and modulus of elasticity, see values in Table II for Beams and Stringers.
1200 lb. *c* Close-Grained Douglas Fir (Inland)	1200	
1200 lb. *c* Close-Grained Larch	1200	
1200 lb. *c* Dense Longleaf or Dense Shortleaf Southern Pine	1200	
1200 lb. *c* Close-Grained Redwood	1200	
1100 lb. *c* Douglas Fir (Coast)	1100	
1100 lb. *c* Douglas Fir (Inland)	1100	
1100 lb. *c* Larch	1100	
1100 lb. *c* Oak	1100	
1100 lb. *c* Close-Grained Redwood	1100	
1000 lb. *c* Port Orford Cedar	1000	
1000 lb. *c* Tidewater Red Cypress	1000	
1000 lb. *c* Oak	1000	
1000 lb. *c* Dense Longleaf Southern Pine	1000	
1000 lb. *c* Close-Grained Redwood	1000	
900 lb. *c* Port Orford Cedar	900	
900 lb. *c* Dense Shortleaf Southern Pine	900	
800 lb. *c* Western Red Cedar	800	

The detailed reasoning basic to these grades will be found by a study of a report of the U. S. Forest Products Laboratory, U. S. Department of Agriculture *Miscellaneous Publication No. 185*, entitled "Guide to the Grading of Structural Timbers and the Determination of Working Stresses," February, 1934. Reference should also be made to the "Working Stresses" appearing in the Appendix to the Standard Specifications for Structural Wood Joist and Plank, Beams and Stringers, and Posts and Timbers (A.S.T.M. Designation: D 245 – 33) of the American Society for Testing Materials.[1]

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 384.

REPORT OF COMMITTEE D-8
ON
BITUMINOUS WATERPROOFING AND ROOFING MATERIALS

Committee D-8 on Bituminous Waterproofing and Roofing Materials, in an appendix to its 1934 annual report as preprinted for the annual meeting, submitted certain proposed extensive revisions of four tentative specifications for asphalt roofing and two proposed tests for bituminous emulsions. After making further changes at the annual meeting, they were subsequently approved[1] by letter ballot of the committee and were then referred to Committee E-10 on Standards with recommendations that they be issued by the Society as tentative. At a meeting of Committee E-10 on August 22, 1934, these recommendations were accepted and the revised specifications and new methods, the titles and designations of which are as follows, have been published in the 1934 *Proceedings*:[2]

Tentative Specifications for:

Asphalt Roofing Surfaced with Coarse Mineral Granules (D 249 - 34 T)
Asphalt Roofing Surfaced with Fine Mineral Granules (D 248 - 34 T)
Asphalt Roofing Surfaced with Powdered Talc or Mica (D 224 - 34 T)
Asphalt Shingles Surfaced with Coarse Mineral Granules (D 225 - 34 T)

The two methods of test for bituminous emulsions: namely, miscibility and determination of water, were incorporated in the Tentative Methods of Testing Emulsified Asphalts (D 244 - 34 T) originally recommended by Committee D-4 on Road and Paving Materials.

In 1931, 1932 and 1933 a progress report from Subcommittee VIII on Accelerated Weathering Tests (O. G. Strieter, chairman) was appended to the annual report of Committee D-8. This subcommittee has continued its investigations and has secured additional information of sufficient interest to warrant its publication. A further progress report from Subcommittee VIII is therefore appended to this report.

RECOMMENDATIONS AFFECTING STANDARDS

I. *Proposed Tentative Standard:*

Proposed Tentative Volume Correction Table for Asphaltic Products.—Committee D-8 joins with Committee D-4 in recommending that the tables designated as Group 0 and Group 1 in the Standard Abridged Volume Correction Table for Petroleum Oils (D 206 – 34)[1] be tentatively approved as a Volume Correction Table for Asphaltic Products. These tables are now in common use by the asphalt industry.

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[1] In submitting these specifications and methods to Committee E-10 on Standards, the committee reported the following results of the letter ballot vote of a total of 36 ballots returned from a committee membership of 49: On each of the four Tentative Specifications for Asphalt Roofing, 32 affirmative, 3 negative and 1 ballot marked "not voting;" Tentative Methods of Testing Emulsified Asphalts (D 244 - 34 T), 33 affirmative, 1 negative and 2 ballots marked "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 955, 951, 947, 944, 926 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 755, 759, 763, 767, 711.

II. Proposed Revision of Standard:

Standard Specifications for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing (D 173 – 27).[2]—In order to allow for customary methods of packing, the committee recommends the following change in these specifications and since this minor modification does not materially affect the specifications, it is recommended that it be considered an editorial change and made immediately:

Section 11.—Change the first sentence to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 11. The rolls of treated cotton fabric shall be wound on [2 by 2-in. wooden] mandrels *not less than 2 in. in diameter or 2 in. square, and* extending *not less than 2 in. nor more than* 4 in. beyond the ends of the rolls.

III. Proposed Revision of Tentative Standards:

Tentative Specifications for Asphalt Roofing Surfaced with Powdered Talc or Mica (D 224 – 34 T).[3]—To meet criticisms received, the committee recommends that these specifications be revised as follows and continued as tentative.

Section 1.—Omit the last sentence which reads as follows:

> Such roofing is intended for use as a roof covering for buildings.

Section 2.—After the words "mineral filler" add the words "substantially insoluble in water."

Section 5 (e).—Change the weight of saturant (soluble in CS_2) per 108 sq. ft. specified for the 55-lb. grade from a minimum of "17.5 lb." to read "17.3 lb."

Section 5 (h).—Change the beginning of this paragraph to read as follows by the addition of the italicized words and the omission of the words in brackets:

> (*h*) Weight of *any 108 sq. ft. roll of* complete roofing [per 108 sq. ft.] *in the shipment.*

Section 11 (a).—Change the first sentence of this section by substituting the words "Washburn & Moen" for "A. S. & W."

Tentative Specifications for Asphalt Shingles Surfaced with Coarse Mineral Granules (D 225 – 34 T).[4]—To meet criticisms received, the committee recommends that these specifications be revised as follows and continued as tentative:

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 127.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1042.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 947 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 763.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 944, (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 767.

Section 2.—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant, then coated on both sides with a hot asphaltic coating compounded with a fine mineral filler *substantially insoluble in water*, and finally surfaced on [one] *the weather* side with mineral granules embedded in the hot asphaltic coating.

Section 5.—Change the beginning of Paragraphs (*f*) and (*g*) of this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

(*f*) Weight of [front] *weather side* coating (soluble in CS_2) per 108 sq. ft.
(*g*) Weight of [back] *reverse side* coating (soluble in CS_2) per 108 sq. ft.

Tentative Specifications for Asphalt Roofing Surfaced with Fine Mineral Granules (*D 248 - 34* T).[1]—To meet criticisms received, the committee recommends, that these specifications be revised as follows and continued as tentative:

Section 1.—Omit the last sentence which reads as follows:

Such roofing is intended for use as a roof covering for buildings.

Section 2.—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant then coated on both sides with a hot asphalt coating compounded with a fine mineral filler *substantially insoluble in water*, and finally surfaced on [one] *the weather* side with fine granules of talc or other mineral material, and of a color as may be mutually agreed upon between the purchaser and seller, embedded in the hot asphaltic coating.

Section 5.—Add to this section a new Paragraph (*g*) given in italics below, and change the present Paragraphs (*f*), (*g*) and (*h*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets, relettering the present Paragraphs (*i*) and (*j*) accordingly:

	GRADES			
	65 LB.		55 LB.	
	MAX., LB.	MIN., LB.	MAX., LB.	MIN., LB.
(*f*) Weight of *weather side* coating (soluble in CS_2) per 108 sq. ft.	[20.0] *15.0*	[10.0] *8.0*	[20.0] *15.0*	[10.0] *8.0*
(g) Weight of reverse side coating (soluble in CS_2) per 108 sq. ft.	....	*2.0*	....	*2.0*
([*g*] *h*) Weight of mineral matter per 108 sq. ft.:				
Passing No. 14 and retained on No. 100 sieve.	17.0	3.0	12.0	3.0
Passing No. 100 sieve	10.0	[3.0] *4.0*	10.0	[3.0] *4.0*
([*h*] *i*) Weight of *any 108 sq. ft. roll of* complete roofing [per 108 sq. ft.] *in the shipment*	....	60.0	....	50.0

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 951 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 759.

Section 11 (*a*).—Change the first sentence of this section by substituting the words "Washburn & Moen" for "A. S. & W."

Tentative Specifications for Asphalt Roofing Surfaced with Coarse Mineral Granules (*D 249 - 34 T*).[1]—To meet criticisms received, the committee recommends that these specifications be revised as follows and continued as tentative:

Section 1.—Omit the last sentence which reads as follows:

> Such roofing is intended for use as a roof covering for buildings.

Section 2.—Change the first sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> 2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant, then coated on both sides with a hot asphaltic coating compounded with a fine mineral filler *substantially insoluble in water*, and finally surfaced on [one] *the weather* side with mineral granules embedded in the hot asphaltic coating.

Section 5.—Change Paragraphs (*c*) to (*j*), inclusive, to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

	[GRADES]			
	[105 LB.]		[90 LB.	
	[MAX., LB.]	[MIN., LB.]	MAX., LB.	MIN., LB.
(*c*) Weight per roll, net avg: No bare edge	....	[97.0]	....	83.0
2 or 3 in. bare edge	....	[95.0]	....	81.0
(*d*) Weight of dry felt per 108 sq. ft.	....	[15.7]	....	10.8
(*e*) Weight of saturant (soluble in CS_2) per 108 sq. ft.	....	[25.1]	....	17.3
(*f*) Weight of [front] *weather side* coating (soluble in CS_2) per 108 sq. ft.	[20.0]	[12.0]	20.0	12.0
(*g*) Weight of [back] *reverse side* coating (soluble in CS_2) per 108 sq. ft.	[5.0]	[2.0]	5.0	2.0
(*h*) Weight of mineral matter per 108 sq. ft. passing No. 6 and retained on No. 100 sieve	[40.0]	[25.0]	40.0	25.0
(*i*) Weight of mineral matter per 108 sq. ft. passing No. 100 sieve	[10.0]	[4.0]	10.0	4.0
(*j*) Weight of *any 108 sq. ft. roll of* complete roofing [per 108 sq. ft.] *in the shipment* (coarse granule surfaced portion)	....	[94.0]	....	80.0

Section 6 (*a*).—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> 6. (*a*) The [weather] surface *of the weather side* shall be uniform in finish and texture. The mineral granules shall be uniformly distributed over the entire surface (except as noted in Paragraph (*b*)) in a smooth layer and shall be [so] firmly embedded in the [asphaltic] *asphalt* coating [that when rubbed vigorously with the hand, sufficient will remain to completely cover the coating].

Section 10 (*a*).—Change the first sentence of this section by substituting the words "Washburn & Moen" for "A. S. & W."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 955 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 755.

Tentative Specifications for Asphalt for Use in Constructing Built-Up Roof Coverings (D 312 - 29 T).[1]—For some time past the committee has felt that these specifications were inadequate from the standpoint of differentiating the products for various types and conditions of use. It has therefore prepared an entirely new table of properties which has been incorporated in the proposed revised specifications appended hereto[2] and which the committee recommends for publication as tentative.

Tentative Method of Test for Coarse Particles in Bituminous Materials by Means of Elutriation (D 313 - 29 T).[1]—This test was specified by reference in the Tentative Specifications for Asphalt for Use in Constructing Built-Up Roof Coverings (D 312 - 29 T). In the proposed revision of these specifications, as given above, an entirely different method of determining coarse particles will be required. The committee therefore recommends that the proposed new Tentative Method of Test for Coarse Particles in Mixtures of Asphalt and Mineral Matter, appended hereto,[3] be accepted as a revision of the present tentative method.

In connection with the various specifications for bituminous roofing materials herein reported, which were considered by Committee D-8 at a meeting on March 8, 1935, Mr. P. H. Walker, acting for H. R. Snoke of the National Bureau of Standards, requested that the published report of the committee record his objection to "the continued use of the toxic and highly inflammable carbon disulfide as a solvent;" also his recommended "use of carbon tetrachloride," and his exception to "the pliability test as being too lenient." He stated that "specifications should require that all test pieces pass the pliability test."

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 48 voting members; 42 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Tentative Volume Correction Table for Asphaltic Products	37	0	5
II. PROPOSED REVISION OF STANDARD			
Specifications for Woven Cotton Fabric Saturated with Bituminous Substances for Use in Waterproofing (D 173 - 27), editorial changes	34	0	8
III. PROPOSED REVISION OF TENTATIVE STANDARDS			
Specifications for Asphalt Roofing Surfaced with Powdered Talc or Mica (D 224 - 34 T)	32	2	8
Specifications for Asphalt Shingles Surfaced with Coarse Mineral Granules (D 225 - 34 T)	32	2	8
Specifications for Asphalt Roofing Surfaced with Fine Mineral Granules (D 248 - 34 T)	32	2	8
Specifications for Asphalt Roofing Surfaced with Coarse Mineral Granules (D 249 - 34 T)	32	2	8
Specifications for Asphalt for Use in Constructing Built-Up Roof Coverings (D 312 - 29 T)	32	3	7
Method of Test for Coarse Particles in Bituminous Materials by Means of Elutriation (D 313 - 29 T)	31	3	8

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, pp. 719, 722 (1929); also 1934 Book of A.S.T.M. Tentative Standards, pp. 752, 770.

[2] See p. 983.—ED.

[3] See p. 1001.—ED.

This report has been submitted to letter ballot of the committee which consists of 48 voting members; 42 members returned their ballots, of whom 37 have voted affirmatively and 2 negatively.

Respectfully submitted on behalf of the committee,

J. M. WEISS,
Chairman.

PRÉVOST HUBBARD,
Secretary.

REPORT OF SUBCOMMITTEE VIII ON ACCELERATED WEATHERING TESTS

In previous reports of Subcommittee VIII on Accelerated Weathering Tests[1] results of cooperative tests were submitted. The purpose of these tests was the standardization of the carbon arc lamp. It was shown that the differences obtained in the test results were mainly due to differences in the intensities of the lamps, especially between lamps using direct current and those operated on alternating current.

Cooperative tests and radiant energy measurements[2] showed that the direct-current lamp with an amperage of 12 to 14 amp. gave practically the same light intensity as the alternating-current lamp operated at an amperage of 15 to 17 amp. As now constructed, the adjustment of the lamps is somewhat difficult because of the lack of sensitivity of the resistance unit.

Further data on the effect of the accelerated weathering cycle as compared with outdoor weathering have been obtained. In this series of tests a total of 798 panels have been exposed, 684 outdoors in different localities and 114 to the accelerated cycle. The method of test was described in a previous report of this subcommittee.[2] The results of these tests show the value of the accelerated cycle in that in all cases the order of failure was the same in both accelerated and outdoor exposures. These tests further show that only an average durability can be determined in the accelerated cycle since the outdoor exposures in different localities varied somewhat owing to differences in weather conditions. Such an average also holds true for a given locality, since the weather conditions vary from year to year.

Only a small fraction of the data obtained can be given here. The following table shows that the panels broke down in the same order of time whether exposed outdoors or to the accelerated weathering cycle:

	Accelerated Weathering Cycle, number of cycles required to reach end point of test	Outdoor Exposures for $1\frac{1}{2}$ yr.	Photograph of Panels
No. 1	28 cycles	Reached end point	Fig. 2
No. 2	28 cycles	Reached end point	Fig. 2
No. 3	28 cycles	Reached end point	.....
No. 4	43 cycles	Faint cracks but no end point	.....
No. 5	65 cycles	No cracks	.....
No. 6	Still perfect after 65 cycles	Perfect	Fig. 1

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 511 (1931); also Vol. 32, Part I, p. 452 (1932).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, pp. 379, 381 (1933).

Figure 1 shows a panel (A1) after 65 cycles of accelerated weathering with duplicate panels (A2 to A7) exposed outdoors for $1\frac{1}{2}$ yr. in various localities. These panels all remained intact and in perfect condition. There are no cracks visible to the eye nor under a magnifying glass (×12).

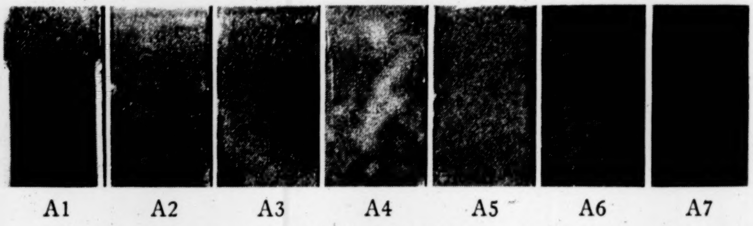

FIG. 1.—Asphalt Panels After Accelerated Weathering and Outdoor Exposure.
Panel A1 After Exposure to 65 Cycles of Accelerated Weathering.
Panels A2 to A7 After $1\frac{1}{2}$-yr. Exposure Outdoors in Various Localities.

The coatings illustrated consisted of 44.2 per cent hard asphalt (by weight), 20.8 per cent soft asphalt and 35.0 per cent slate flour, the latter passing a No. 100 but retained on a No. 200 sieve. Both asphalts were prepared from the same Venezuelan flux but were blown to different degrees of hardness. The hard asphalt had a softening point (ring-and-ball method) of 107 C., the soft asphalt one of 90 C., while the resulting asphalt-filler mixture had a softening point of 107 C.

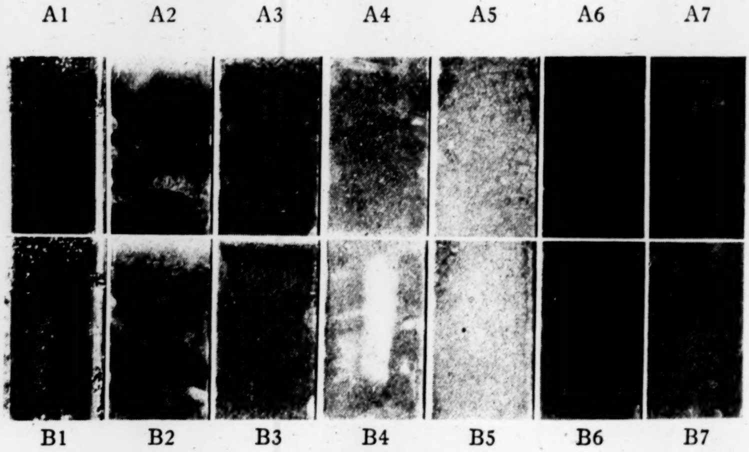

FIG. 2.—Panels Showing Two Asphalts After Accelerated Weathering and Outdoor Exposure.
Panels A1 and B1 Were Exposed to 65 Cycles of Accelerated Weathering.
Panels A2 to A7 and B2 to B7 Were Exposed Outdoors in Various Localities for $1\frac{1}{2}$ yr.

The coatings illustrated in the upper row consisted of equal parts of the hard and the soft asphalts, the mixture having a softening point (ring-and-ball method) of 99.5 C. The panels in the lower row were a blend of 25 per cent hard asphalt with 75 per cent soft asphalt, the resulting mixture having a softening point of 94 C.

Figure 2 shows two asphalts similarly exposed (panels A1 and B1 after accelerated weathering, and panels A2 to A7 and B2 to B7 after outdoor exposure). All of these coatings show cracks except A4 and B4, exposed in a mild climate lacking sun and moisture. The coatings exposed to the accelerated cycle reached the endpoint (cracks down to aluminum base) in 28 cycles but were carried through the 65 cycles. Because of the intensity of the accelerated weathering cycle some asphalts, of which these two are representative, tend to groove and show so-called "hummocks." This behavior is seldom found in the milder outdoor exposure. Another series of accelerated exposures is being made with the lamp at a lower intensity. Figure 3 shows the asphalts used in panels A1 and B1 of Fig. 2 after exposure to this milder cycle. These coatings have not reached the end-point. They have passed the stage where "hummocks" should appear, but they still remain smooth and no doubt will continue so.

Hummocking is due to the intensity of the light and heat period and the susceptibility of some asphalts. From the testing point of view, however, such behavior is not objectionable, since the comparison with outdoor exposures has shown (see Nos. 1 and 2, in table above) that the "hummock" samples break down in the accelerated cycle in the same order as they do outdoors.

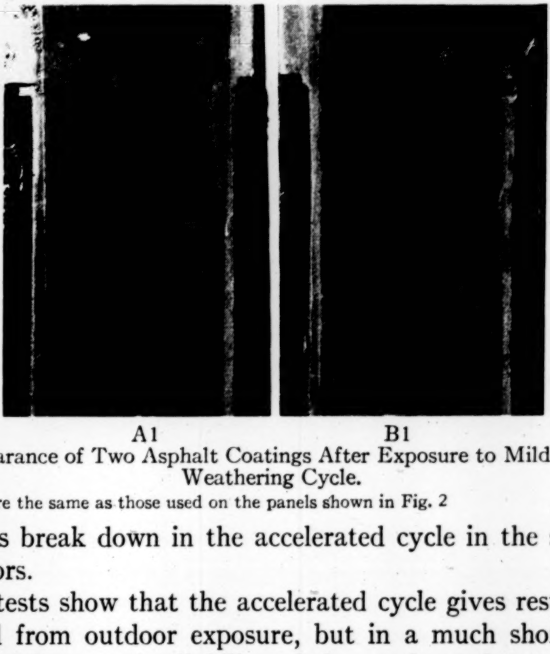
A1 B1

FIG. 3.—Appearance of Two Asphalt Coatings After Exposure to Milder Accelerated Weathering Cycle.

The coatings were the same as those used on the panels shown in Fig. 2

All these tests show that the accelerated cycle gives results similar to those obtained from outdoor exposure, but in a much shorter period of time. The usefulness and reliability of the accelerated test is thus established. The results furthermore show that the cycle used is reliable and so the Proposed Method for Accelerated Weathering Tests on Bituminous Materials[1] may be accepted as satisfactory.

Some refinements in the method are still necessary before it can be recommended for publication as tentative. Such refinements will be in the nature of better controlled conditions of light, temperature and humidity.

Respectfully submitted on behalf of the subcommittee,

O. G. STRIETER,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 381 (1933).

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS

During the year Committee D-9 on Electrical Insulating Materials held two meetings and expects to hold a third during the annual meeting of the Society in June at Detroit, Mich. The meetings were held in November, 1934, and March, 1935, with an average attendance of 86 members and visitors. It is with satisfaction that the committee reports that at these meetings numerous projects have had active consideration which has resulted in recommendations for additions and changes in the standards for which Committee D-9 is responsible.

Subsequent to the 1934 annual meeting, the committee presented to the Society through Committee E-10 on Standards revisions of the following three tentative methods and one standard method. The revised tentative methods and the revision of the standard were accepted for publication as tentative[1] by Committee E-10 at a meeting held on August 22, 1934, and appear in the 1934 *Proceedings:*

Revised Tentative Methods of:

Testing Untreated Paper Used in Electrical Insulation (D 202 – 34 T)[2]
Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 34 T)[2]
Testing Electrical Insulating Materials for Resistance to Impact (D 256 – 34 T)[2]

Tentative Revision[2] of Standard Methods of:

Testing Molded Materials Used for Electrical Insulation (D 48 – 33)

Through Sectional Committee C59 on Electrical Insulating Materials, functioning under the procedure of the American Standards Association, the following standards of Committee D-9 were submitted to the A.S.A. and approved as American Standards on January 30, 1935:

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 33) (A.S.A. No. C59.1 – 1935)
Standard Methods of Testing Electrical Insulating Oils (D 117 – 33) (A.S.A. No. C59.2 – 1935)
Standard Methods of Test for Resistivity of Insulating Materials (D 257 – 33) (A.S.A. No. C59.3 – 1935)

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[1] In submitting these revisions to Committee E-10 on Standards, Committee D-9 reported the following results of the letter ballot vote of a total of 36 ballots returned from a committee membership of 66: Tentative Methods of Testing Untreated Paper Used in Electrical Insulation (D 202 – 34 T), 26 affirmative, none negative, and 10 ballots marked "not voting;" Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 34 T), 22 affirmative, none negative, and 14 ballots marked "not voting;" Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 – 34 T), 19 affirmative, 2 negative, and 15 ballots marked "not voting"; Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 33), 19 affirmative, none negative, and 17 ballots marked "not voting."

[2] *Proceedings,* Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1007, 1055, 995, 1277 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 849, 893, 821, 1205.

Recommendations Affecting Standards

As a result of the year's work, the committee is presenting a new tentative method of test and many recommendations for revisions of standards and tentative standards as noted in brief form below together with the results of the letter ballot. The revisions being recommended are indicated in detail in the Appendix, each item being accompanied by a brief explanation of the reason for the proposed change or addition, together with any data available to indicate the scope of the investigation involved in arriving at the recommendations.

I. Proposed Tentative Standard.—Subcommittee I on Insulating Varnishes, Paints and Lacquers (C. F. Hanson, chairman) found that there was a sufficient demand both from users and importers of shellac to prepare standard methods of testing, particularly to distinguish its characteristics for insulating purposes. There had also been presented to the Society through the American Standards Association a request to develop test methods for shellac when used in insulation. The committee undertook this work some time ago, using as a basis the present Standard Methods of Sampling and Testing Shellac (D 29 – 33).[1] The proposed Tentative Methods of Testing Shellac Used for Electrical Insulation, appended hereto,[2] include a procedure for the determination of polymerization time which it is felt should be a desirable measurement to be made on shellac used for insulation. The test for polymerization time is an indication of the curing time of shellac and also an indication of whether a given shellac will cure properly. When shellac is used as an insulation in electrical apparatus, it is desirable that the shellac shall be not thermoplastic throughout the operating temperature range of the apparatus. This end is effected by heating the shellac insulation for a prolonged period of time at an elevated temperature and this process is known as curing the shellac. During this curing period, the shellac undergoes an internal change, making it less susceptible to softening and most likely adding durability to the shellac.

The committee accordingly recommends that the proposed Tentative Methods of Testing Shellac Used for Electrical Insulation be accepted for publication as tentative, as appended hereto.[2]

II. Proposed Revision of Standards.—The committee recommends that editorial changes be made in the Standard Methods of Testing Electrical Porcelain (D 116 – 34) to become effective immediately, and also proposes modifications of the Standard Methods of Testing Electrical Insulating Oils (D 117 – 33) for publication as a tentative revision, as indicated in the Appendix.

III. Proposed Revision of Tentative Standards.—The committee is presenting, as indicated in the Appendix, editorial changes in three tentative standards and is also proposing revisions of ten tentative standards, as follows, with the recommendation that as revised they be continued as tentative:

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 678.
[2] See p. 1077.—Ed.

Tentative Methods of:

- Testing Varnishes Used for Electrical Insulation (D 115 - 34 T)
- Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (D 150 - 34 T)
- Testing Solid Filling and Treating Compounds Used for Electrical Insulation (D 176 - 34 T)
- Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 - 34 T)
- Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T), editorial changes
- Testing Laminated Tubes Used in Electrical Insulation (D 348 - 34 T)
- Testing Laminated Round Rods Used in Electrical Insulation (D 349 - 34 T)
- Testing Flexible Varnished Tubing Used for Electrical Insulation (D 350 - 32 T)
- Test for Grading Natural Mica (D 351 - 33 T)
- Testing Pasted Mica Used in Electrical Insulation (D 352 - 32 T), editorial changes
- Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 34 T)

Tentative Specifications for:

- Flexible Varnished Tubing Used in Electrical Insulation (D 372 - 33 T)
- Black Bias-Cut Varnished Cloth Tape Used for Electrical Insulation (D 373 - 34 T), editorial changes

IV. Tentative Standards Continued as Tentative.—The following two tentative standards under the jurisdiction of the committee have been tentative for more than three years without revision for the reasons indicated:

Tentative Method of Test for Determining the Electrical Insulating Qualities of Slate (D 273 - 27 T), which is under the joint jurisdiction of Committee D-9 and Committee D-16 on Slate, has been retained as tentative since 1927. The work on methods for determining conducting paths by Subcommittee VII on Electrical Tests (E. S. Lee, chairman) has now reached a very satisfactory solution. A simple method employing a spark coil and suitable exploring electrodes gives satisfactory results. This method will be referred to Committee D-16 before being submitted to letter ballot of Committee D-9. Accordingly, it is recommended that this tentative method be continued in its present form pending further consideration of the revision.

Tentative Method of Test for Comparing the Thermal Conductivities of Solid Electrical Insulating Materials (D 325 - 31 T) is not being revised or adopted although it has been tentative for four years. Through Subcommittee VII, measurements are being continued by those who are interested and it is recommended that it be continued as tentative until its adequacy is well determined.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 70 members; 43 members returned their ballots, with the results shown in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARD			
Methods of Testing Shellac Used for Electrical Insulation	24	0	19
II. PROPOSED REVISIONS OF STANDARDS			
Methods of Testing Electrical Porcelain (D 116 - 34), editorial changes	20	0	23
Methods of Testing Electrical Insulating Oils (D 117 - 33)	30	0	13
III. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Methods of Testing Varnishes Used for Electrical Insulation (D 115 - 34 T)	23	0	20
Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (D 150 - 34 T)	33	0	10
Methods of Testing Solid Filling and Treating Compounds Used for Electrical Insulation (D 176 - 34 T)	26	1	16
Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 - 34 T)	30	1	12
Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 - 34 T), editorial changes	26	0	17
Methods of Testing Laminated Tubes Used in Electrical Insulation (D 348 - 34 T)	25	0	18
Methods of Testing Laminated Round Rods Used in Electrical Insulation (D 349 - 34 T)	26	0	17
Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (D 350 - 32 T)	23	0	20
Methods of Test for Grading Natural Mica (D 351 - 33 T)	22	0	21
Testing Pasted Mica Used in Electrical Insulation (D 352 - 32 T), editorial changes	18	1	24
Methods of Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (D 392 - 34 T)	17	0	26
Specifications for Flexible Varnished Tubing Used in Electrical Insulation (D 372 - 33 T)	22	0	21
Specifications for Black Bias-Cut Varnished Cloth Tape Used for Electrical Insulation (D 373 - 34 T), editorial changes	24	0	19

ACTIVITIES OF SUBCOMMITTEES

Although the recommendations affecting standards are to some degree a measure of the work accomplished by the committee during the year, they represent only those items which the committee was able to bring to a definite conclusion at this time. There are, however, many other projects on which the committee has been working. A brief summary of some of its activities is presented.

Throughout the various subcommittees, there is considerable activity in connection with the study of the influence of ambient conditions on test results which has resulted in the establishment of a special Subcommittee on Conditioning (D. T. May, chairman). This subcommittee was organized during the past year to include a representative from each of the regular subcommittees. It will undertake to study those standards which have conditioning requirements with a view to coordination and also with the hope of being able to develop suitable facilities of general application.

In the field of insulating oils, a large amount of work has been carried on by Subcommittee IV (E. A. Snyder, chairman) in connection with the sludge test in the presence of a catalyst and short-time sludge tests. The possibility of electrical titration has been further advanced and should aid in acidity and neutralization measurements on oils.

Subcommittee IV has also organized a Section on Tests of Cable Oils. Since this is a subject of considerable research and discussion by other societies, it is felt well to summarize the present extent of this program. Test methods are being investigated along the following lines:

1. Sampling and conditioning of samples.
2. Aging and oxidation of cable oils primarily to study electric stability of aged and oxidized oils.
3. Power-factor, dielectric-constant and resistivity tests of cable oils.
4. Volumetric gas content of insulating oils.
5. Power factor of treated papers.
6. Viscosity determination of small samples of oil primarily for use where it is possible only to extract small samples from a cable for test.

Mr. E. A. Snyder, the chairman of Subcommittee IV functions as Technical Adviser on Insulating Oils to the U. S. National Committee of the International Electrotechnical Commission. During the year, the subcommittee translated and discussed a number of papers received from foreign countries on insulating oils. It will prepare this year a report for the U. S. National Committee, to be submitted to the central office in London, of its work over the past two years.

In Subcommittee V on Ceramic Products (Porcelain, Glass, Etc.) (L. E. Barringer, chairman), there has been established a new section which will undertake the study of glass for insulating purposes. This new activity brought into Committee D-9 several new members in order to have an adequate representation on the new section. Several meetings have been held.

Due to the active interest in power-factor measurements of insulating materials, both at commercial and high frequencies, Subcommittee VII on Electrical Tests (E. S. Lee, chairman) has been called upon by many of the other subcommittees to develop and recommend suitable methods for the measurement of the materials in which they are interested. As a result, this subcommittee has reviewed the procedures so as to provide simple and effective equipment for the different materials. Certain of the additions to the tentative methods being recommended at this time are the result of this work. The subcommittee has further work in connection with approving circuits, particularly for power-frequency measurements. A Section on Power-Factor Measurements at Ultra High Frequencies has also been organized.

A section of Subcommittee VIII on Insulating Papers and Fabrics (Treated and Untreated) (R. W. Chadbourn, chairman), which was established to develop suitable methods of thickness measurement, developed several years ago the Tentative Methods of Test for Thickness of Solid Electrical Insulation (D 374 – 34 T). This section has since been active through the various other subcommittees trying to coordinate the method of measuring thickness with a view to arriving possibly at a few methods that will have universal application. Its progress has been highly successful to date and several test methods under the jurisdiction of Subcommittee III on Plates, Tubes, and Rods (Dean Harvey, chairman) are being revised this year as a result of this work. There is also under consideration in this field, at the request of the National Electrical Manufacturers Association, a study of thickness-measuring methods for wide sheets up to 50 in.

The Section on Insulated Papers of Subcommittee VIII has had to consider in its work the test methods which might be developed through the Technical Association of the Pulp and Paper Industry. Feeling that effective work could not be accomplished without close cooperation between Committee D-9 and T.A.P.P.I., efforts were made in this direction. During the year, through the Executive Committee of the Society, arrangements have been made to set up definite cooperation so that the test methods developed should have general acceptance and application. This, it is felt, will be very beneficial to the work of this subcommittee.

Viscosimeters for use on varnishes have received considerable attention and a study is also being made with a view to developing simple control-type devices for production work. In the field of impact testing, the study of the possibility of impact fatigue measurements is being made. The measurement of arc resistance of sheet and plate insulation at high voltage is advanced to the point where several laboratories expect to undertake comparative tests using a method which has been reported on. Other work which has been productive includes investigation of coefficient of expansion and occluded gases of filling and treating compounds and further refinement of the methods of grading mica.

This report has been submitted to letter ballot of the committee, which consists of 70 members; 43 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

T. SMITH TAYLOR,
Chairman.

E. J. RUTAN,
Secretary.

APPENDIX

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR ELECTRICAL INSULATING MATERIALS

In this Appendix are given proposed revisions in certain standard and tentative standards covering electrical insulating materials which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the standard appears in its present form.

Editorial Revision of Standard Methods of Testing Electrical Porcelain (A.S.T.M. Designation: D 116 - 34):[1]

Based on a discussion as to the scope of these methods and also on suggestions received from the Sectional Committee on Electrical Insulating Materials, Committee D-9 recommends that the following editorial changes be made immediately:

Section 1.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> 1. These methods are intended to apply to porcelain [which is to be] *and other vitrified ceramic materials* used [for] *in the manufacture of* electrical insulating [purposes] *parts.*

Omit the last two sentences of the Note to this section which read as follows:

> It is believed that this difference is due to the fact that the glaze may not "fit" the porcelain uniformly and therefore cause stresses to be set up within the porcelain body. Mechanical strength tests on unglazed and glazed specimens may therefore be of value as giving an indication of the "fit" of the glaze to the porcelain body.

Sections 5, 9 and 15.—Change Paragraph (*a*) of these sections to read as follows by the omission of the words in brackets:

> (*a*) Not less than five specimens shall be tested [in the normal condition].

Change Paragraph (*d*) of Sections 5 and 15 and Paragraph (*e*) of Section 9 to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> The tests shall be made at a temperature of about [21] *20* C. ([70] *68* F.).

Section 21 (*c*).—Change to read as follows by the omission of the words in brackets:

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 170.

(*c*) Not less than five specimens shall be punctured [in their normal condition] at a normal room temperature of about 20 C. (68 F.).

Section 34 (*a*).—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

34. (*a*) The specimens shall be dried for 2 hr. in the oven at 120 C. (248 F.) *and* then cooled in a desiccator to the approximate room temperature [and]. *Each specimen shall be* weighed immediately *upon removal from the desiccator.*

Tentative Revision of Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117 - 33):[1]

The attention of Committee D-9 has been called to the fact that in this method no provision has been made for the measurement of specific gravity or for evaluing the color of an oil. As these tests are used by various members, it was felt desirable to include provision for them. Accordingly, reference is made to standard tests already adopted by the Society for such measurements. These standards have been available for some time to those dealing with petroleum and lubricating oils and, in the estimation of the committee, are satisfactory for insulating oils. The following revision is accordingly recommended for publication as tentative:

New Sections.—Add the following as new Sections 9 and 10, renumbering the remaining sections accordingly:

9. *Specific Gravity.*—The test for specific gravity shall be made in accordance with the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287) of the American Society for Testing Materials.

10. *Color.*—The test to determine color shall be made in accordance with the Tentative Method of Test for Color of Lubricating Oils by Means of A.S.T.M. Union Colorimeter (A.S.T.M. Designation: D 155 - 34 T) of the American Society for Testing Materials.

Revision of Tentative Methods of Testing Varnishes Used for Electrical Insulation (A.S.T.M. Designation: D 115 - 34 T):[2]

The test for non-volatile matter by weight in these methods has been studied with the view of expanding it so that it will be applicable to impregnating varnishes of the phenolic-resin type. Five laboratories have participated in trial tests and have obtained reliable results with the proposed modified procedure. Accordingly, it is recommended that the present test be replaced by the proposed expanded test appearing below and that the methods, as revised, be continued as tentative:

Test for Non-Volatile Matter by Weight.—Replace the present test in Sections 21 and 22 by the following, renumbering the remaining sections accordingly:

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1087.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1082 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 926.

21. *Apparatus.*—The apparatus required consists of a chemical balance, a glass thermometer having a range of 0 to 150 or 200 C. and accurate within 1 C., a constant-temperature oven of uniform temperature, a stoppered bottle and flat bottom metal drying dishes. Each metal drying dish shall have an inside diameter of approximately $2\frac{3}{4}$ in. (7 cm.) and a depth of approximately $\frac{5}{16}$ in. (8 mm.).

NOTE.—A standard single-friction tin can cover having a diameter of $2\frac{13}{16}$ in. is suitable for use as a drying dish.

22. *Test Specimen.*—The specimen shall consist of approximately 1.5 g. (1.35 g. to 1.65 g.) of the sample of varnish taken from the shipment.

23. *Procedure: (a) Preparing the Specimens.*—A portion of the sample of varnish shall be placed in a stoppered bottle or weighing pipette and weighed. Approximately 1.5 g. (1.35 g. to 1.65 g.) shall be transferred from the weighed stoppered bottle to a weighed drying dish which has previously been heated for 30 min. at 135 C. and cooled in a desiccator. The stoppered bottle with the remaining contents shall be weighed again. The exact weight of the specimen transferred to the drying dish shall be determined by difference. A total of three specimens shall be prepared from the contents of the stoppered bottle.

(*b*) *Drying the Specimens.*—The specimens shall be placed in the constant temperature oven within 30 min. after preparation. The specimens shall be heated for a period of 3 hr. at the temperature designated, as follows:

Impregnating varnishes of the phenolic-resin type.......	132 to 138 C.
Other types of insulating varnishes....................	105 to 110 C.

NOTE.—In a gravity type of oven which depends upon the natural circulation of air for uniformity of temperature, only one shelf must be used for supporting the specimens, and the bulb of the thermometer for indicating the temperature shall be in close proximity to the specimens.

(*c*) *Weighing the Dried Specimens.*—At the termination of the 3-hr. heating period, the specimens shall be removed to a desiccator for cooling to room temperature. Each specimen shall be weighed immediately upon removal from the desiccator.

(*d*) *Calculation.*—The ratio of the weight of the dried specimen to the weight of the specimen in the original state expressed as a percentage is the percentage of non-volatile matter by weight.

24. *Report.*—The report shall include the following:

(*a*) The type of varnish
(*b*) The oven temperature
(*c*) The percentage of non-volatile matter

Revision of Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 – 34 T):[1]

Committee D-9 had been requested to suggest a suitable container for holding oil samples during the power factor and dielectric constant measurements. Several designs have been investigated. The cell proposed is one already approved by the committee for solid insulating compounds as noted below. This cell is simple and inexpensive to construct and lends itself readily to usual measurements of liquid insulation. It is not suited for high precision measurements. Committee D-9 accordingly recommends that the following be added as an Appendix to Methods D 150 and that the methods as thus revised be continued as tentative:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1029 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 871.

CELL FOR POWER FACTOR AND DIELECTRIC CONSTANT MEASUREMENTS OF ORDINARY INSULATING OILS

A cell that has been found suitable for the purpose of measuring the power factor and dielectric constant of oil (and solid filling and treating compounds) is shown in Appendix IV of the Tentative Methods of Testing Solid Filling and Treating Compounds Used for Electrical Insulation (D 176 - 35 T).[1] The cell is suitable for the common types of insulating oils but oils of extra high quality would require that the insulation be entirely out of the field. The power factor of insulation in this cell shall be of at least the same order as the power factor of the oil to be tested. In addition, the insulation must be chosen so that it will not be appreciably affected by the oil or cleaning solvents and must not absorb sufficiently to electrically contaminate subsequent test samples.

This cell has the following points of simplicity and efficiency:

1. Ease of insulating electrodes.
2. Large area of electrodes in compact form, the outer one of which serves as a container. This outer electrode is also exposed directly to the heating medium and aids in rapid changes from one temperature to another and also promotes uniform temperature in the comparatively thin layer of oil in contact with it.
3. Comparative ease in assembling and disassembling the cell and in cleaning.

Revision of Tentative Methods of Testing Solid Filling and Treating Compounds Used for Electrical Insulation (A.S.T.M. Designation: D 176 - 34 T):[2]

These methods as written are applicable only to gas-free compounds. Since materials containing gas will not be so uniform, high precision is not justified. To cover these materials, certain changes and additions to the methods are desirable. The added methods are thoroughly qualified by being based on standard practice. Committee D-9 accordingly recommends that Methods D 176 be revised as follows and continued as tentative:

Section 1.—Add a note to this section to read as follows:

NOTE.—Before testing under these methods it may be necessary to degasify (*a*) materials which tend to entrap gases (usually due to high viscosity) and/or (*b*) materials which tend to froth on heating. (See Appendix I.).

Appendix I.—Add the following as a new Appendix I, renumbering the remaining appendixes accordingly:

APPENDIX I

DEGASIFICATION OF SOLID FILLING AND TREATING COMPOUNDS

Compounds having high viscosity may be degasified by heating in a vacuum oven or in a cell fitted with a special cover with vacuum connection similar to the cover shown in Fig. A1, Appendix II.

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[1] See p. 1006.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 965 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 791.

In either method the temperature and vacuum should be high enough and the time long enough to insure the driving off of mechanically entrapped gases, but should tend to decompose the compound as little as possible. A gas-free condition is indicated when bubbles of gas no longer appear at the surface of the compound.

Specific Gravity.—Add the test for specific gravity appended hereto[1] as Sections 4 to 6 of these methods, renumbering the remaining sections accordingly.

Coefficient of Expansion.—Replace the present test for coefficient of expansion in Sections 4 and 5 of the methods by the revised procedure appended hereto,[1] renumbering the present Sections 6 to 14 as Sections 9 to 17, and add the three new methods (Method C, Specific Gravity; Method D, Pycnometer-Contraction; and Method E, Pycnometer-Expansion), also appended hereto[1] to the methods as Sections 18 to 27, inclusive, renumbering the remaining sections accordingly.

Section 18.—Add to the present Section 18 a new paragraph as Paragraph (*c*), to read as follows:

> (*c*) Voltage shall be applied at a value less than 1000 v. and raised at the rate of 1000 v. per sec. until breakdown occurs.

Revision of Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (A.S.T.M. Designation: D 229 – 34 T):[2]

In accordance with the policy of Committee D-9, a study has been made of several existing tentative standards under its jurisdiction with a view to unifying the method of thickness measurements. Since the committee prepared the Tentative Method of Test for Thickness of Solid Electrical Insulation (D 374 – 34 T) it has been considered desirable to modify the other methods so that they provide for thickness measurements in keeping with this tentative method. Committee D-9 accordingly recommends that Methods D 229 be revised as indicated below and continued as tentative:

Sections 10 and 16.—Change Paragraph (*b*) of these sections to read as follows by the addition of the italicized words:

> (*b*) The thickness and width of each specimen in inches (or centimeters) *expressed to the nearest 0.001 in.*

Section 21 (*a*).—Change to read as follows by the addition of the italicized words:

> (*a*) The dimensions of each specimen in inches (or centimeters) *expressed to the nearest 0.001 in.*

Resistance to Impact.—There has been found a need for a test for measuring the resistance to impact. Accordingly, a new section has been prepared providing for this test by referring to the Tentative Methods of

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[1] The tests for specific gravity and coefficient of expansion have been incorporated in the revised tentative methods, see pp. 1007, 1008 and 1012, respectively.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1055 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 893.

Testing Electrical Insulating Materials for Resistance to Impact (D 256-34 T). It is felt that these methods will answer the need for measurements of this characteristic on sheet and plate electrical insulation. It is accordingly proposed to add the following as a new Section 22, renumbering the remaining sections accordingly:

22. (*a*) *Resistance to Impact.*—Resistance to impact shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (A.S.T.M. Designation: D 256-34 T) of the American Society for Testing Materials.

(*b*) *Specimen.*—Specimens for the Charpy test may be notched or unnotched, as desired, according to conditions of service, and for the Izod test shall be notched. Specimens shall be cut both lengthwise and crosswise of the sheet.

NOTE.—The unnotched specimen gives a higher strength than the notched specimen and the ratio of the strength of the unnotched specimen to that of the notched specimen varies with different materials.

Editorial Revision of Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (A.S.T.M. Designation: D 256-34 T):[1]

Committee D-9 recommends that the following editorial changes in these methods be made immediately:

Section 4.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and the omission of the words in brackets:

4. (*a*) For insulating materials other than ceramic materials, the specimen shall conform to the dimensions shown in Fig. 3. The notch, *when used*, may be milled, filed or molded provided the bottom of the resulting notch is smooth, straight and free from scratches. For molded material, the thickness of the molded specimen, that is, the dimension parallel to the application of the molding pressure and lengthwise of the notch, may be any thickness of ½ in. or less agreed upon as representative of the cross-section in which the particular material is to be used. For sheet material, the thickness shall be the thickness of the sheet except that it shall not exceed ½ in. *Sheet material, when thicker than ½ in. may be tested either edgewise or flatwise, as specified (Note 1), and when tested flatwise, the notch shall be made in the original surface.* When the individual specimen is less than ½ in. in thickness, the test piece shall be a composite specimen consisting of a number of individual thin specimens, aggregating as nearly as possible ½ in. in thickness [and]. *They shall* all [being] *be* accurately aligned with each other [when] *and shall be* tested *edgewise.* Specimens of molded insulating material shall be conditioned before testing by drying in an oven at 50 C. ±5 C. (122 F. ±9 F.) for 48 hr., followed by cooling to room temperature in a desiccator. Tests shall be made at room temperature.

Notes 1 and 2 following Section 5 are applicable to both Sections 4 and 5. It is therefore recommended that the present note following Section 4 be deleted and that Notes 1 and 2 of Section 5 be transposed to Section 4 and a suitable reference to the notes added in both sections.

Section 5.—Change the sixth sentence of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 995 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 821.

When the individual specimen is less than ½ in. in thickness, the test piece shall be a composite specimen consisting of a number of individual thin specimens aggregating as nearly as possible ½ in. in thickness [and]. *They shall* all [being] *be* accurately aligned with each other [when] *and shall be* tested *edgewise.*

Revision of Tentative Methods of Testing Laminated Tubes Used in Electrical Insulation (A.S.T.M. Designation: D 348 – 34 T):[1]

For the reasons indicated under Methods D 229 – 34 T, above, Committee D-9 recommends that Methods D 348 be revised as indicated below and continued as tentative:

Section 4.—Change to read as follows by the addition of the italicized words:

4. Five specimens shall be tested. The *average* inside and outside diameters *determined from at least two measurements 90 deg. apart* shall be measured at the groove *to the nearest 0.001 in.* and the cross-section area shall be calculated from these dimensions. The metal plugs shall be assembled with the tube as shown in Fig. 1. This assembly shall then be grasped in the V-notched jaws of the testing machine.

Section 6.—Change Paragraphs (*a*), (*b*) and (*c*) to read as follows by the addition of the italicized words:

(*a*) The *average* inside diameter of the specimen *expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.*

(*b*) The *average* outside diameter of the specimen *expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.*

(*c*) The *average* outside diameter of the reduced section *expressed to the nearest 0.001 in.*, if a groove was used.

Section 10.—Change Paragraphs (*a*) and (*b*) to read as follows by the addition of the italicized words:

(*a*) The *average* inside and outside diameters of the specimen *expressed to the nearest 0.001 in., each determined from at least two measurements 90 deg. apart.*

(*b*) The *average* wall thickness of the specimen *expressed to the nearest 0.001 in.*

Section 13.—Change Paragraphs (*a*) and (*b*) to read as follows by the addition of the italicized words:

(*a*) The *average* inside and outside diameters of the specimen.

(*b*) The *average* wall thickness of the specimen.

Section 17.—Change Paragraphs (*a*) and (*b*) to read as follows by the addition of the italicized words:

(*a*) The inside and outside diameters of the specimen *expressed to the nearest 0.001 in.*

(*b*) The wall thickness of the specimen *expressed to the nearest 0.001 in.*

Revision of Tentative Methods of Testing Laminated Round Rods Used in Electrical Insulation (A.S.T.M. Designation: D 349 – 34 T):[2]

For the reasons indicated under Methods D 229 – 34 T, above, Committee D-9 recommends that Methods D 349 be revised as indicated below and continued as tentative:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1064 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 831.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1051 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 827.

Sections 7, 11 and 15.—Change Paragraph (*a*) of these sections to read as follows by the addition of the italicized words:

(*a*) The diameter of the specimen *expressed to the nearest 0.001 in., determined from at least two measurements 90 deg. apart.*

Revision of Tentative Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (A.S.T.M. Designation: D 350 - 32 T):[1]

A number of changes are being proposed in these methods. The micrometer originally specified has been changed to conform to the Tentative Methods of Test for Thickness of Solid Electrical Insulation (D 374 - 34 T). The method of making dielectric strength tests has been revised, and a note added cautioning the tester against the use of the standard gage rods as inner electrodes. The ignition test has been deleted and the rate-of-burning method revised and clarified. The bunsen burner has been substituted for the Meker burner. These revisions together with certain minor changes of an editorial nature have been incorporated in the revised methods appended hereto[2] which Committee D-9 accordingly recommends for publication as tentative.

Revision of Tentative Methods of Test for Grading Natural Mica (A.S.T.M. Designation: D 351 - 33 T):[3]

Committee D-9 recommends that these methods be revised as follows and continued as tentative:

Section 3.—The tentative standard A.S.T.M. chart referred to in this section as Fig. 1 (Plate I) has been corrected, as attached hereto,[4] so as to make the chart areas for grades 2 and 4 correspond to the tabulated areas.

Section 4.—Change the table appearing in the note to this section to read as follows by the addition of the italicized figures and the omission of those in brackets:

GRADE	AREA OF RECTANGLE, SQ. IN.	MINIMUM DIMENSION OF ONE SIDE
Extra special	60 to [79⅞] *80*	.....
Special	48 to [59⅞] *60*	.....
A-1	36 to [47⅞] *48*	4 in.
1	24 to [35⅞] *36*	3 in.
2	15 to [23⅞] *24*	2 in.
3	10 to [14⅞] *15*	2 in.
4	6 to [9⅞] *10*	1½ in.
5	3 to [5⅞] *6*	1 in.
5½	2½ to [2⅞] *3*	1 in.
6	1 to [2⅜] *2½*	¾ in.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 902 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 922.

[2] See p. 1080.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 837 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 836.

[4] See p. 1035.—ED.

Editorial Revision of Tentative Methods of Testing Pasted Mica Used in Electrical Insulation (A.S.T.M. Designation: D 352 – 32 T):[1]

Committee D-9 recommends that the following editorial changes in these methods be made immediately:

Section 13.—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

> 13. The specimen shall be ½ by ½ in. by the thickness of mica. [Five] *Six* specimens shall be tested. *These shall be cut from a given sheet in accordance with the pattern shown in Fig. 2.*

New Figure.—Add the accompanying Fig. 1 showing the pattern for location of test specimens as Fig. 2 of the tentative methods.

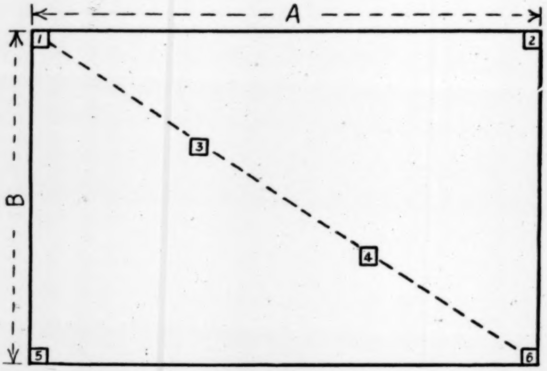

Fig. 1—Pattern for Location of Test Specimens.

Size of sheet: A = 36 in.; B = 24 in.
Numbered specimens each ½ by ½ in.

Revision of Tentative Methods of Testing Molding Powders Used in Manufacturing Molded Electrical Insulators (A.S.T.M. Designation: D 392 – 34 T):[2]

Further consideration has been given during the year to the powder pourability test. This test determines how readily molding powder will feed through the hoppers and deliver uniform weights of material into the dies of the tableting machines. Committee D-9 accordingly recommends that the following new test be added to these methods as Sections 20 to 23, inclusive, and the methods continued as tentative:

POWDER POURABILITY

20. *Purpose.*—The powder pourability test is to determine how readily molding powders will feed through the hoppers and deliver uniform weights of material into the dies of tableting machines by measuring the time of flow of a standard quantity

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 911 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 838.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1001 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 843.

through a standard funnel. The test is generally adaptable quantitatively only to materials of bulk factor 3.0 or less (see Section 17).

21. *Apparatus.*—The apparatus required consists of a funnel mounted as shown in Fig. 1, and a stop watch.

22. *Procedure.*—A sample of the powder, equivalent to 100 times the molded specific gravity in grams (see Section 18 (*b*)) shall be taken. This sample shall be worked on a paper until there is no tendency of the material to pack or cake. With the apparatus assembled, as shown in Fig. 1, the small end of the funnel shall be closed with the hand or with a suitable flat strip of material, and the sample poured lightly into the funnel, avoiding any tendency to pack it. The bottom of the funnel shall then be opened quickly, and the stop watch shall be started at the same instant. The powder shall be allowed to run from the funnel as freely as it will and the watch shall be stopped at the instant the last grains leave the funnel.

NOTE.—Correct mold charges are those weights which produce the constant molded volume of the piece to be molded and shall be so measured. Comparable quantities of material for this test are therefore some multiple of the molded specific gravity, 100 being taken as convenient.

23. *Report.*—The report shall state the time in seconds required for the funnel to discharge or that the material will not run through the funnel, if so found (Note).

NOTE.—Molding powders which are not measurable by this test generally do not feed well without special feeders.

Revision of Tentative Specifications for Flexible Varnished Tubing Used in Electrical Insulation (A.S.T.M. Designation: D 372 - 33 T):[1]

These specifications have been available for two years. As a result, several changes are being suggested based on experience in the use of the specifications. A minor change involves the omission of the test requirement for ignition time for grade C tubing and the revision of the rate-of-burning test. The rate-of-burning test applies only to grade C tubing and should be sufficient for distinguishing this grade. Committee D-9 accordingly recommends that the specifications be revised as indicated below and continued as tentative:

Scope.—Add the following note at the end of the scope clause:

NOTE.—The term "varnished tubing" as used in these specifications refers to braided cotton sleeving coated or impregnated and coated with lacquer or a combination of lacquer and varnish or other similar coatings.

Section 2.—Change Paragraph (*b*) to read as follows by the addition of the italicized word and the omission of the words in brackets:

(*b*) The cotton sleeving shall be uniformly [coated with varnish] *treated*, and the finished tubing shall be reasonably free from defects such as pimples, blisters, wrinkles, cracks, and similar imperfections.

Section 4.—In the note following the table of diameters, change the words "gage size," which appear in the third, sixth and ninth lines, to read "diameter."

Section 6.—Omit the word "minimum" after the figures specifying the number of hours of baking.

Section 7.—Omit Paragraph (*a*) which reads as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 815 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 788.

7. (*a*) Tubing furnished under these specifications as grade C non-flammable tubing shall show a value of not less than 4 seconds for ignition time and shall cease to burn immediately upon removal from the flame.

Change Paragraph (*b*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets, renumbering this paragraph as Section 7:

7. Tubing furnished under these specifications as grade C [flame-resistant tubing may ignite immediately and, on removal from the flame, the rate of burning shall be not less than] ***shall require at least*** 45 seconds [per inch of] ***to burn a*** length ***of 2.54 cm. (1 in.).***

Section 10.—Change to read as follows by the omission of the words in brackets:

10. Each package shall be marked with the name or trade mark of the manufacturer, the total number of feet, [and] the size, [number] and color of the tubing.

Editorial Revision of Tentative Specifications for Black, Bias-Cut, Varnished Cloth Tape Used for Electrical Insulation (A.S.T.M. Designation: D 373-34 T):[1]

These specifications have been available for about one year. As a result of their use, several minor changes have been suggested. These apply to the measurement of average thickness, and a warning concerning the method of making the flexibility test. An additional change is being made to liberalize the requirements in connection with oil-immersed tape, permitting the manufacturer to suggest the packing oil rather than making it a matter of specification. Committee D-9 accordingly recommends that the following editorial changes in these specifications be made immediately:

Section 7.—Change the second sentence to read as follows by the omission of the words in brackets:

The average thickness shall be determined from the ten measurements taken on a specimen before testing in accordance with Section 15 [the five measurements on the specimen before testing in accordance with Section 16, and the other five measurements on the specimen before testing in accordance with Section 17].

Section 11.—Add a second sentence to this section to read as follows:

Care shall be taken not to bring the finger nails into contact with the tape surfaces while making the crease.

Section 20.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

20. Oil-immersed tape shall be supplied in suitable oil-tight cans with easily removable lids. The purchaser shall specify the number, width and length of rolls [and the type of oil] to be supplied in each can. ***The type of oil used for packing shall be subject to the approval of the purchaser.***

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 959 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 782.

REPORT OF COMMITTEE D-10
ON
SHIPPING CONTAINERS

Committee D-10 on Shipping Containers held a meeting at New York City on December 6, 1934, to consider the activities of the committee members since the last meeting in Chicago, June 24, 1931, and to formulate a definite program for active work.

At this meeting considerable discussion ensued as to the field of work of Committee D-10. It was brought out that the development of specifications for shipping containers was undertaken by the committee some fifteen or more years ago primarily because there was no other organization in a position to carry on this work, for which there was a very pressing need. The specifications as finally written by the committee were in the form of requirements for design and construction of containers, this being the only basis upon which the committee could proceed at that time. Specifications dealing with matters of design and construction lie, in general, outside the functions of A.S.T.M. It was the consensus of opinion of those present at the meeting that the necessity for the Society to do this type of work had largely passed; that the scope of the committee should in the future be confined to those functions which were admittedly within the field of A.S.T.M. activities, such as methods of testing containers, and test methods and specifications for materials to be used in containers when no other standing committee of the Society was preparing such specifications; and that the present specifications for shipping containers should be withdrawn.

The committee accordingly recommends that the following four tentative specifications under its jurisdiction be withdrawn:

Tentative Specifications for:

Wooden Boxes, Nailed and Lock-Corner Construction, for the Shipment of Canned Foods (D 44 – 20 T)
Canned Foods Boxes, Wirebound Construction (D 45 – 17 T)
Wooden Boxes, Nailed and Lock-Corner Construction (D 68 – 22 T)
4-One Boxes and Similar Type Boxes (D 118 – 21 T)

This recommendation has been submitted to letter ballot of the committee, which consists of 19 members; 19 members returned their ballots, of whom 15 voted affirmatively, 1 negatively, and 3 marked their ballots "not voting."

Upon the request of Mr. J. A. Newlin to be relieved of the chairmanship of the committee, Mr. Edward Dahill was nominated for his office and unanimously elected by letter ballot of the committee to fill the unexpired term.

No plans are being made to hold a meeting of the committee during the annual meeting of the Society, but the chairman plans to hold sectional meetings in New York City and in Chicago in the very near future to lay before the members certain proposals which would change the primary objects of Committee D-10. Essentially these proposals are that the committee should drop any further work towards preparing specifications for containers and devote its time and energy to preparing procedures for making tests on the materials and accessories used in the construction of containers, the designing or acceptance of apparatus for making these tests, and the procedures to be followed in making tests of the completed containers.

This report has been submitted to letter ballot of the committee, which consists of 19 members; 15 members returned their ballots, of whom 14 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

EDWARD DAHILL,
Chairman.

C. A. PLASKETT,
Secretary.

REPORT OF COMMITTEE D-11
ON
RUBBER PRODUCTS

Committee D-11 on Rubber Products has held one meeting during the year in addition to the one held during the 1934 annual meeting. This was at Philadelphia, Pa., on March 7, 1935, in connection with the Spring Group Meetings of A.S.T.M. Committees. Following the custom of the past several years, the committee omitted the regular fall meeting.

During the past year there have been a number of changes in the personnel of the committee. Provision has been made for more adequate representation on Committee D-11 of the National Electrical Manufacturers Association. To this end, Mr. C. R. Boggs, chairman of N.E.M.A. representatives, and Messrs. S. J. Rosch, R. A. Schatzel, E. D. Youmans, H. H. Weber, and G. W. Zink have been designated to represent N.E.M.A. in place of Mr. W. H. Bassett, Jr. The committee has suffered the loss by resignation of two members, Mr. F. M. Waring and Mr. L. C. Peterson. New members include Messrs. R. H. Titley, Public Service Electric and Gas Co.; W. R. Marsden, Kelly-Springfield Tire Co.; R. W. Chadbourne, Edison Electric Illuminating Company of Boston; H. R. Ferguson, The Thiokol Corp.; and J. J. Corcoran, Signal Section of the Association of American Railroads. K. O. Tooker, The Hoover Co. has been replaced by Mr. C. E. Boger, and Messrs. Cranor and Wiegand of the Binney & Smith Co. have been replaced by Mr. C. R. Haynes.

Subsequent to the 1934 annual meeting the committee presented to the Society through Committee E-10 on Standards revised Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 34 T). Some revisions were also presented in the Tentative Methods of Test for Abrasion Resistance of Rubber Compounds (D 394 – 34 T), which had been adopted at the June meeting, and additional revisions were made in the Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound, (D 27 – 34 T), and for Insulated Wire and Cable: Performance Rubber Compound (D 353 – 34 T). The revised Specifications for Insulating Tape were mentioned in last year's report of the committee and represented the result of extensive studies which had been given to the existing specifications with a view toward bringing them in agreement with present practice. A number of changes were made including addition of materials requirements, change in tensile strength requirements, changes in the fusion test, addition of a thickness requirement, changes in the sampling provisions, and inclusion of a storage guarantee. The changes in the Abrasion Test Methods were deemed necessary primarily to clarify the use of the comparison standards specified. The additional revisions to the Wire Specifications were made mainly to provide for the use of a new table on thickness of insulation and alternating test voltage. This table replaced two tables which have been used practically without change for more than ten years. As a result of progress in the electrical industry the old tables had become obsolete. The new table which represents several years' work on the part of a section of Subcommittee V on Insulated Wire and Cable was recommended to bring the specifications in line with present practice. The above revisions were accepted for publication as tentative[1] by Committee E-10 at a meeting held on August 22, 1934, and appear in the 1934 *Proceedings*.[2]

Through Sectional Committee C-59 on Electrical Insulating Materials, functioning under the procedure of the American Standards Association, the Standard Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 – 24) were submitted to the A.S.A. and approved as American Standard on January 30, 1935.

RECOMMENDATIONS AFFECTING STANDARDS

I. Proposed Tentative Standards:

Proposed Tentative Methods of Physical Testing of Rubber Products (General Requirements).—For a number of years Committee D-11 has been responsible for the Standard Methods of Physical Testing of Rubber Products (D 15 – 32). These methods were originally adopted in 1915 and covered a few of the methods generally used in testing rubber products. During the period since their adoption, the methods have been of great service and have been revised from time to time to keep them up to date but meanwhile new methods have been developed and have assumed importance. Some of these have found a place among the Society's standards as separate tentative methods and in many cases have been too comprehensive to be included in the original standard. Furthermore, difficulty has been encountered in keeping Methods D 15 sufficiently broad to be applicable to all classes of product. Consequently, inconsistencies have arisen. It therefore seems advisable to revise the original standard methods in a comprehensive manner and it is proposed to do this by removing from Methods D 15 the portions which refer to particular types of tests, putting these in separate tentative methods and to revise Methods D 15 so that they will include only test requirements of general applicability. The committee has prepared such revisions which it recommends to the Society for publication as tentative. It is proposing to withdraw the Standard Methods of Physical Testing of Rubber Products (D 15 - 32), replacing them with the proposed Tentative Methods of Physical Testing of Rubber Products (General Requirements), appended hereto.[1] In these proposed general methods matters relating to facilities for testing, sampling and preparation of samples, age and condition of samples, temperature of test and retests are given. Specific details of test methods such as are used for tension, adhesion and hydrostatic burst tests have been eliminated and, with the exception of hydrostatic tests, are recommended in revised and rewritten form as separate tentative test methods. In the case of hydrostatic burst tests, it is believed that since these are covered in the test methods which have been approved for wrapped and braided hose they should not be presented elsewhere, especially as they apply in practice principally to these products. It is also felt that there is no more justification for inclusion of tension and adhesion tests in Methods D 15 than would be true of methods for testing abrasion resistance, hardness or numerous other properties. The committee believes that the proposed plan as outlined offers a more satisfactory basis than the present one for future development of test standardization.

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[1] In submitting these recommendations to Committee E-10 on Standards, Committee D-11 reported the the following results of the letter ballot vote of a total of 22 ballots returned from a committee membership of 76; Tentative Specifications for Rubber Insulating Tape (D 119 – 34 T), 15 affirmative, 0 negative and 7 ballots marked "not voting;" Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 34 T), 16 affirmative, 0 negative and 6 ballots marked "not voting;" Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (D 353 – 34 T); 16 affirmative, 0 negative and 6 ballots marked "not voting;" Tentative Methods of Test for Abrasion Resistance of Rubber Compounds (D 394 – 34 T), 18 affirmative, 0 negative and 4 ballots marked "not voting."

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1145, 1101, 1128, 1150 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 991, 945, 972, 996.

Proposed Tentative Methods of Tension Testing of Vulcanized Rubber.—These methods include standard procedures for determining stress-strain properties, tensile strength, ultimate elongation and permanent set of the usual grades of soft vulcanized rubber. They are a revision of material heretofore included in the Standard Methods of Physical Testing of Rubber Products (D 15 - 32). In revising them, however, the methods have been considerably amplified and brought into conformity with modern practice. In agreement with the program discussed above, it is recommended that the proposed Tentative Methods of Tension Testing of Vulcanized Rubber, as appended hereto,[2] be accepted for publication as tentative.

Proposed Tentative Methods of Test for Adhesion of Vulcanized Rubber (Friction Tests).—These methods of test are suitable for use in measuring the strength of adhesion between plies of fabric bonded with rubber or, in many cases, the adhesion of the rubber layer in articles made from rubber attached to another material. They represent a revision and amplification of material formerly included in the Standard Methods of Physical Testing of Rubber Products (D 15 - 32). The former standard included detailed procedure of test for adhesion using only the dead-weight method. The proposed new methods include procedures using both the dead-weight method and a machine method and cover use of both strip and ring specimens. In conformity with the program already outlined, the committee recommends that the proposed Tentative Methods of Test for Adhesion of Vulcanized Rubber, appended hereto,[1] be accepted for publication as tentative.

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[1] See p. 1153.—ED.

[2] See p. 1159.—ED.

II. Proposed Revision of Standard:

Standard Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 – 34).[2]—The committee recommends that Section 7 of these specifications be revised by removing the requirement that free sulfur shall not be less than 0.5 per cent and substituting a requirement that free sulfur shall not exceed $1\frac{1}{4}$ per cent. The reason for this change is that since adoption of the 0.5 per cent free sulfur requirement progress has been made in the manufacture of rubber lining for fire hose and the requirement no longer serves any useful purpose. Furthermore, the question has been raised that this requirement may hamper manufacturers in the production of a rubber compound free from any tendency to generate sulfuric acid under certain conditions met with in practice. It appears, however, that some restriction on free sulfur is necessary and desirable as too high a sulfur content is objectionable. The proposed revision has been requested by the Underwriters' Laboratories of the Sectional Committee on Rubber-Lined Fire Hose which functions under the procedure of the American Standards Association. The revision has been approved by all manufacturers subscribing to the Underwriters' Laboratories' Factory Inspection and Label Service on cotton rubber-lined fire hose except one who has given no reasons for not approving it. It has also been approved by the Specifications Committee of the Rubber Manufacturers Association. Furthermore, it is believed that the proposal is more in accord with present-day practice than the former requirement. The committee recommends that this revision become effective immediately and accordingly asks for the necessary nine-tenths vote at the annual meeting in order that it may be submitted to letter ballot of the Society.

III. Proposed Revision of Tentative Standards:

Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 34 T).[3]—The committee is recommending a number of technical and editorial changes in these specifications,[1] as indicated in the Appendix to this report. The committee has carefully reviewed these changes and believes that they will improve the tentative specifications by making them more consistent and more definite. Important additions are the inclusion of Nos. 18 and 16 wire in Table IV, but insulated for 300 volts only, and a new Section E on Finish, covering the use of saturants, which is to replace the present section. Other changes include a requirement on number of test specimens to be used in connection with aging tests, specifying the lead for lead sheath cables in conformity with A.S.T.M. specifications, establishment of a limit for thickness of cable tape, and the rewriting of the procedure for high voltage testing of single and multiple conductor cables to make it more precise. A revision of the flexible stranding portion of Table I is also recommended.

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[1] See p. 1173.—Ed.

[2] 1934 Supplement to Book of A.S.T.M. Standards, p. 149.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1101 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 945.

Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (D 353 – 34 T).[2]—The committee is recommending revisions of these specifications[1] as indicated in the Appendix. These revisions are intended to correspond with those recommended above in Specifications D 27 – 34 T, and will keep the specifications in conformity with each other.

Tentative Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 – 34 T).[3]—Revisions are being recommended in these specifications as indicated in the Appendix to this report. The tackiness requirement has been rewritten to avoid possible misunderstanding and the description of the micrometer for thickness measurement has been changed to conform with that specified elsewhere for use with rubber products. The number of specimens to be tested in each case has been defined, and the number of thickness and width measurements to be made has been stated. Changes have also been made in the rejection provisions to permit rejection without testing of material that is not properly marked or tagged.

Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 34 T).[4]—Changes similar to those described above in connection with Specifications D 69 – 34 T are recommended in these specifications, as indicated in the Appendix. The committee considers these changes desirable and in the interests of definiteness and precision.

IV. *Withdrawal of Standard:*

Standard Methods of Physical Testing of Rubber Products (D 15 – 32).[5]—The committee is recommending the withdrawal of these methods and their replacement by the proposed Tentative Methods of Physical Testing of

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[1] Subsequent to the annual meeting Committee D-11 presented to the Society additional revisions of these Tentative Specifications for Insulated Wire and Cable, see Editorial Note, p. 428.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1128 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 972.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1139 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 985.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1145 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 991.

[5] 1933 Book of A.S.T.M. Standards, Part II, p. 1154.

Rubber Products (General Requirements), as mentioned earlier in this report.

V. Tentative Standard Continued as Tentative:

Tentative Specifications for Rubber Pump Valves (D 151 – 31 T).—The committee recommends that these specifications which have been tentative for more than three years be continued in that status for the present. Adoption of the specifications as standard has been considered but not approved because of the use of a hardness test differing from that specified in the Standard Method of Test for Hardness of Rubber (D 314 – 34). Substitution in the specifications of the standard test is being considered.

The recommendations appearing in this report have been submitted to letter ballot of the committee which consists of 83 members; 34 members returned their ballots, the results being as follows:

Items	Affirmative	Negative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
Methods of Physical Testing of Rubber Products (General Requirements)	33	0	1
Methods of Tension Testing of Vulcanized Rubber	31	0	3
Methods of Test for Adhesion of Vulcanized Rubber (Friction Test)	31	0	3
II. PROPOSED REVISION OF STANDARD			
Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use (D 296 – 34), immediate adoption	20	0	14
III. REVISIONS OF TENTATIVE STANDARDS			
Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 34 T)	19	0	15
Specifications for Insulated Wire and Cable: Performance Rubber Compound (D 353 – 34 T)	19	0	15
Specifications and Tests for Friction Tape for General Use for Electrical Purposes (D 69 – 34 T)	22	0	12
Specifications and Tests for Rubber Insulating Tape (D 119 – 34 T)	23	0	11
IV. WITHDRAWAL OF STANDARD			
Methods of Physical Testing of Rubber Products (D 15 – 32)	33	0	1

ACTIVITIES OF SUBCOMMITTEES

Subcommittee II on Belting (C. H. Zieme, chairman).—Since this subcommittee has completed its work on preparation of methods of test for power transmission belting, it has decided to devote its attention to the development of similar test methods applicable to conveyor belting and the formation of a new section of the subcommittee to undertake this work has been authorized.

Subcommittee V on Insulated Wire and Cable (C. B. Martin, chairman).—In addition to the work of this subcommittee which is presented in the form of revisions of the tentative specifications under its jurisdiction as referred to earlier in this report, much progress has been made in the separate sections engaged in special studies. Section 1 is giving further consideration to the test voltages of Table IV in the wire and cable specifications, following comments which have been received. This section is also progressing in its work on specifications for rubber insulation resistant to acids, alkalies and oil. Section 2 has completed the preparation of methods for corona-resistance testing of rubber insulation. Its report has been approved subject to minor changes that may be necessary in order to secure agreement with a committee of the Insulated Power Cable Engineers Association which is considering the same subject. Section 3 on Saturants and Finishes has completed the preparation of new sections which are included in the recommended revisions given in the Appendix. It is also working on performance tests for saturants and finishes. Section 4 on 60 per cent Rubber Sheaths has completed a specification covering the compound. It is preparing a table on the stranding of the wire and when this is agreed upon it is intended to present the specification for separate publication.

Subcommittee IX on Insulating Tape (M. F. Skinker, chairman).—In addition to its work in preparing revisions of existing tentative specifications, as mentioned earlier in this report, this subcommittee is investigating methods of test for aging qualities of insulating tape. At present, a co-operative test program is in progress.

Subcommittee X on Physical Testing of Rubber Products (H. M. Frecker, chairman).—The subcommittee has made substantial progress in the work looking toward the preparation of a compilation of A.S.T.M. Standard Methods of Test for Rubber Products. The plans for publication of such a volume and a tentative outline have been agreed upon and considerable work has been done in eliminating inconsistencies existing in the present specifications and test methods. The subcommittee believes that it will be possible to publish the first edition of this volume during the current year.

Subcommittee XIV on Abrasion Tests for Rubber Products (G. S. Haslam, chairman).—The subcommittee has devoted its attention during the year to ways and means of securing better reference standard rubber specimens for abrasion tests. It also appreciates the fact that if such standards can be established they will be suitable not only for abrasion testing but also as a reference base in other methods of test. At first it was thought that the materials for preparation of standard rubber compounds for test purposes could be controlled by establishing central depots. This was not found practical and attention was then given to the possibility of making available, through a central laboratory, standard rubber test specimens having certified and tested properties. This plan now appears hopeful and definite interest has been shown on the part of two laboratories, namely, V. L. Smithers, Inc., and the National Bureau of Standards. Numerous details involving the procedures and specifications remain to be worked out and work is being continued along these lines.

Subcommittee XV on Life Tests for Rubber Products (R. A. Schatzel, chairman).—Test methods covering the Geer oven test and the oxygen bomb test have been completed by this subcommittee and it is expected that the methods will be in form to present to the Society for publication as tentative through Committee E-10 on Standards during the summer.[1] The subcommittee has also decided to prepare a method for testing the effect on rubber compounds of air at elevated pressure and temperature. This test, which is commonly called the air bomb test, is assuming increasing importance for service evaluation of rubber compounds designed to resist heat and oxidation. It is particularly applicable and widely used for such products as inner tubes for truck tire service. The subcommittee believes that standardization of the method and test conditions is highly desirable. A section of the subcommittee under the chairmanship of Mr. A. W. Carpenter has been organized to study the existing equipment and draw up a proposed method.

Subcommittee XVII on Rubber Products for Vibration Absorption (J. J. Allen, chairman).—This subcommittee has continued during the year its work in studying methods of test for compression set of rubber. The Society has accepted for publication as tentative the Method of Test for Compression Set of Vulcanized Rubber (D 395 – 34 T) in which the compression set is obtained under constant load conditions. Comment has been received by the subcommittee that it is often desirable to measure this property under constant deflection and the subcommittee has decided that a standard method of test is needed for use in this case. Such a method is in preparation and it is hoped that it may be in form to present to the Society for publication through Committee E-10 on Standards during the year. The subcommittee has also continued its work on hardness testing and, though correlation of different methods and instruments has not been considered practical, further work along these lines is in progress since the subcommittee recognizes that if at all possible such correlation would be helpful. As new work, the subcommittee believes that attention might well be given to methods for measuring permanent set under conditions of shear and also vibration.

Subcommittee XVIII on Dynamic Fatigue Testing for Rubber Products (W. L. Sturtevant, chairman).—Substantial progress has been made by this subcommittee in the preparation of fatigue testing methods for rubber compounds. Three methods for testing resistance to flex-cracking of soft rubber compounds are being prepared and also one method for testing flexing life of rubber used in fabric-rubber combinations such as belts and tire carcasses. The flex-cracking methods may be designated as (1) the Du Pont method in which the specimens made into a belt are flexed over pulleys; (2) the DeMattia or flex-stretching method in which test strips are rapidly and repeatedly elongated until cracking occurs and (3) the

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[1] Subsequent to the annual meeting Committee D-11 presented to the Society new Tentative Methods of Test for Accelerated Aging of Vulcanized Rubber, see Editorial Note, p. 428.—ED.

R. S. L. method in which cracking is induced by rapid controlled bending. The method for testing flexing life of rubber fabric combinations uses the flexing machine which was studied by the former Subcommittee XVI on Flexing Tests and has already been described in the reports of this committee. It is hoped that these methods may be completed and agreed upon so they may be presented to the Society for publication as tentative through Committee E-10 on Standards during the summer.[1]

Subcommittee XIX on Tests for Properties of Rubber and Rubber-Like Materials in Liquids (O. M. Hayden, chairman).—This subcommittee has completed the survey mentioned in last year's report. Of 159 questionnaires sent out, 35 laboratories completed and returned the questionnaires, and 25 other replies were also received. The replies indicated that the chief interest in testing rubber and rubber-like materials in liquids is in oils and solvents, although acids, alkalies, anti-freeze compounds, alcohol, glycerin, creosote, disinfectants, lacquer thinners, liniments, serums and antitoxins were also mentioned. No agreement was indicated as to methods of test, either in method of conducting the test or in evaluating and recording the results, with the exception of the insulated wire industry. All agreed that the rate of deterioration is affected by size, shape, thickness and grain of samples and by temperature of test and possibly other factors but each seemed to have a different method for determining the resistance of the rubber. Following consideration of this survey the subcommittee decided to investigate the effect of the more important factors and has started as its first project the determination of suitable shape and size of test specimens for a standard test. Specimens in the form of cubes and spheres have been prepared and are being tested in five cooperating laboratories.

This report has been submitted to letter ballot of the committee which consists of 83 members; 34 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. A. DEPEW,
Chairman.

ARTHUR W. CARPENTER,
Secretary.

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[1] Subsequent to the annual meeting Committee D-11 presented to the Society new Tentative Methods of Test for Flexing of Rubber Products, see Editorial Note, p. 428.—ED.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-11 on Rubber Products presented to the Society through Committee E-10 on Standards the following additional recommendations:

Proposed Tentative Methods of:

Test for Accelerated Aging of Vulcanized Rubber
Test for Adhesion of Vulcanized Rubber to Metal
Test for Flexing of Rubber Products

Proposed Revision of Tentative Specifications for:

Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 35 T)
Insulated Wire and Cable: Performance Rubber Compound (D 353 – 35 T)

The above recommendations were accepted by Committee E-10 on September 28, 1935; the new methods and the specifications in their revised form appear respectively on pp. **1167**, **1180**, **1186**, **1115** and **1141**.

APPENDIX

PROPOSED REVISIONS IN TENTATIVE STANDARDS FOR RUBBER PRODUCTS

In this Appendix are given proposed revisions in certain tentative standards covering rubber products which are referred to earlier in this report. In connection with each title is given the reference to the publication in which the tentative standard appears in its present form.

Revision of Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (A.S.T.M. Designation: D 27 – 34 T):[1]

Table I.—Change this table from its present form to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

TABLE I.—STRANDING OF INSULATED CONDUCTORS.

(*1*) For intermediate sizes use stranding for next larger size.

(*2*) In assembly column, "37 by 19 rope lay" signifies 37 strands of 19 wires assembled like a rope.

(*3*) *Flexible stranded Nos. 16 and 18 A.w.g. shall consist of No. 30 A.w.g. wires bunched and bound with a soft cotton wind or other material.*

(*4*) Conductors of No. 0000 and smaller are often made solid and this table of stranding should not be interpreted as excluding such practice.

Size of Conductors	Standard Concentric Stranding,[a] Number of Wires	Flexible Stranding	
		Number of Wires	Assembly
2 000 000 cir. mils	127	703	37 by 19 rope lay
1 500 000 cir. mils	91	703	37 by 19 rope lay
1 000 000 cir. mils	61	427	61 by 7 rope lay
500 000 cir. mils	37	427	61 by 7 rope lay
300 000 cir. mils	37	259	37 by 7 rope lay
0 000 A.w.g	19	133	19 by 7 rope lay
1 A.w.g	19	[91] *133*	[Concentric] *19 by 7 rope lay*
2 A.w.g	7	[91] *133*	[Concentric] *19 by 7 rope lay*
4 A.w.g	7	[61] *49*	[Concentric] *7 by 7 rope lay*
8 A.w.g	*7*	*49*	*7 by 7 rope lay*
10 A.w.g	7	37	Concentric
16 A.w.g	7	26	Bunched
18 A.w.g	7	16	Bunched
[20 A.w.g.]	[7]	[10]	[Bunched]

[a] The standard concentric stranding in this table agrees with Table XII of Circular No. 31, "Copper Wire and Cables," U.S. Bureau of Standards; and also Table II of Standard No. 30 "Wires and Cables" of the American Institute of Electrical Engineers.

Section 12 (d).—Add the following sentence after the second sentence of this section:

> In multiple conductor cables the individual conductors shall not be braid-covered unless specified.

Table IV.—Omit the first sentence, which reads as follows, from Note 3 of this table:

> For d.c. systems over 2000 volts consult the manufacturer.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1101 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 945.

Add the following sentence as Note 5:

NOTE 5.—For non-leaded submarine cables, $\frac{1}{32}$ in. should be added to the specified respective walls of insulation in Table IV for all sizes and voltages.

Add the following italicized figures to the table to be inserted above the present data referring to "0 to 600 rated circuit voltage":

RATED CIRCUIT VOLTAGE	SIZE OF CONDUCTOR, A.W.G. NUMBERS	INSULATION, THICKNESS ON EACH CONDUCTOR, SIXTY-FOURTHS OF AN INCH		TEST VOLTAGE, KV.	
		GROUNDED	UNGROUNDED	GROUNDED	UNGROUNDED
0 to 300.........	*No. 18 to No. 16*	*2*	*2*	*1*	*1*

Section 17 (a).—Change from its present form: namely,

17. (*a*) The average thickness of the insulation shall be not less than that given in Table IV. The minimum thickness shall be within 95 per cent of the prescribed thickness for insulations less than $\frac{4}{64}$ in. and within 90 per cent of the specified thickness for insulations from $\frac{4}{64}$ in. to $\frac{18}{64}$ in., inclusive.

to read as follows:

17. (*a*) The average thickness of the insulation shall be not less than 95 per cent of the thickness specified in Table IV for insulations less than $\frac{4}{64}$ in. thick and not less than 90 per cent of the specified thickness for insulations of $\frac{4}{64}$ in. and over.

Section 18.—Change to read as follows by the addition of the italicized words and figures and the omission of the words in brackets:

18. Each coil, reel, or length of wire or cable, after vulcanization [and before the application of any covering other than tape or braid used in vulcanization] shall successfully withstand the application of an alternating voltage of not less than that [given] ***prescribed*** in Table IV for a period of 5 minutes. (*See Sections 46 and 47.*)

New Section 34.—Renumber as a new Section 34 the present Paragraph (*a*) of Section 37, changing the remaining section numbers accordingly.

New Sections 35 and 36.—Add the following new sections; and number as Section 37 the Paragraphs (*b*) to (*f*) of the present Section 34:

35. *Sampling for Aging Tests.*—For aging tests the wire shall be sampled as follows:

No samples shall be selected where the quantity is less than 2000 ft. of wire or cable.

For sizes less than 250,000 cir. mils one sample shall be selected for each quantity ordered between 2000 ft. and 50,000 ft. of wire or cable and one additional sample for each additional 50,000 ft. thereafter.

For sizes 250,000 cir. mils and over one sample shall be selected for each quantity ordered between 2000 ft. and 25,000 ft. of wire or cable and one additional sample for each additional 25,000 ft. thereafter.

36. *Test Specimens.*—Nine test specimens of similar size and shape shall be prepared from each sample selected in accordance with Paragraph (*a*), three for the determination of the initial or unaged properties, three for the oxygen bomb test and three for the Geer oven test. One specimen of each three shall be tested and the other two held as spares except that where only one sample is selected all three specimens shall be tested and the average of the results reported.

Section 46.—Change from its present form: namely,

46. (*a*) ***Immersion in Water.***—The outer surface of the insulation of complete insulated wires and cables shall be grounded while being electrically tested. If the insulation is not provided with a conducting covering, and if the covering is not liable to injury by water, the ground shall be obtained by immersing the insulated wire or cable in water for at least 12 hours and testing at the end of that period while immersed. If the outer covering is susceptible to injury by immersion, the insulated conductor shall be tested before the application of such covering.

(*b*) In the case of multiple-conductor cables, without waterproof over-all jacket of insulation, no immersion test shall be made on finished cables, but only on the individual conductors before assembling.

to read as follows:

49. ***High Voltage Testing:*** (*a*) ***General.***—Where insulated conductors are subjected to a high voltage test in water they shall be immersed in a grounded water bath and tested while still immersed.

(*b*) ***Single Conductor.***—Single conductors shall be tested after 12-hr. immersion and without covering except a tape or braid applied before vulcanization.

Rubber sheathed conductors shall be immersed and tested after the sheath is applied.

Where a metallic sheath is applied, the conductors shall be retested against the sheath.

(*c*) ***Multiple Conductor.***—The individual conductors of multiple conductor cables shall be tested before assembling as prescribed in Paragraph (*b*).

After assembly each conductor shall be tested against the adjacent conductors. Where a metallic sheath is applied each conductor shall in addition be tested against the sheath.

Cables having a rubber or other non-metallic waterproof sheath shall be immersed for 12 hr. and the conductors tested against ground. Cables covered with cable tape and braid or double braid with a weather-resistant finish shall not be immersed for testing.

Section 50.—Add the following sentence at the end of this section:

The nominal thickness shall be 0.012 in. and not less than 0.011 in.

Section 54 (*c*).—Omit this section which reads the same as the new sentence being added to Section 12 (*d*).

Section 57.—In the first sentence of the last paragraph change the word "pressure" to "weight."

Sections 59 and 60.—Omit these present sections under (*E*) Finish and insert the new Sections 62 to 67, as appended hereto,[1] renumbering the remaining sections accordingly.

Section 61.—Change from its present form: namely,

61. Lead sheaths shall consist of commercially pure lead (approximately 99.85 per cent) without flaws and tightly formed about the taped core of the cable.

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[1] See p. 1136.—ED.

to read as follows:

62. Lead sheaths shall consist of Grade II Chemical Lead or Grade III Common Lead, not less than 99.85 per cent pure as specified in the Standard Specifications for Pig Lead (A.S.T.M. Designation: B 29) of the American Society for Testing Materials. It shall be obtained from properly branded pig lead.

Lead sheaths shall be tightly formed around the core of the wire or cable.

Appendix II.—Omit Paragraph (*e*) which reads the same as the new Note 5 to Table IV and also delete Paragraphs (*c*) and (*d*).

Revision of Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (A.S.T.M. Designation: D 353 – 34 T):[1]

Section 5 (a).—Change from its present form: namely,

5. (*a*) The average thickness of the insulation shall be not less than that given in Table I. The thickness of the insulation at the thinnest part shall be not more than 10 per cent less than the specified thickness, but in no case shall such 10 per cent allowance exceed 0.031 in.

to read as follows:

5. (*a*) The average thickness of the insulation shall be not less than that given in Table I. The minimum thickness shall be not less than 95 per cent of the specified thickness for insulations less than $\frac{4}{64}$ in. and not less than 90 per cent of the specified thickness for insulations of $\frac{4}{64}$ in. and over.

Section 6.—Change to read as follows by the addition of the italicized words and figures and the omission of the words in brackets:

6. Each coil, reel or length of wire or cable after vulcanization [and before the application of any covering other than tape used in vulcanization] shall successfully withstand the application of an alternating voltage of not less than that given in Table I for a period of 5 minutes. (*See Sections 30 and 31.*)

Table I.—Make the same changes in this table as are recommended in Table IV of the Tentative Specifications D 27 – 34 T above.

New Section.—Add the following as a new Section 18 to appear before the heading "Aging Tests," renumbering the present sections accordingly:

18. *Tensile Strength, Tensile Stress, Set, Elongation Retests.*—Where tested in accordance with Sections 14, 15, 16 and 17, if a specimen fails to conform to any one of the requirements for tensile strength, tensile stress, set, or elongation at rupture specified in Section 4, two additional specimens shall be taken from the same sample and the average of the results shall determine whether the material conforms to the requirements.

Section 18.—Renumber as Section 19 and replace Paragraph (*a*) by new Paragraphs (*a*) and (*b*) identical with those recommended in the revised Section 34 of the Tentative Specifications D 27 – 34 T above relettering the present Paragraphs (*b*) to (*g*) as (*c*) to (*h*).

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1128 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 972.

Section 29.—Make the same change in this section as is recommended in Section 46 of the Tentative Specifications D 27 – 34 T above.

Appendix I.—Make the same change in this Appendix as is recommended in Appendix II of the Tentative Specifications D 27 – 34 T above.

Revision of Tentative Specifications and Tests for Friction Tape for General Use for Electrical Purposes (A.S.T.M. Designation: D 69 – 34 T):[1]

Section 6 (*a*).—Change the last sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> *Unless otherwise specified one specimen from* each sample roll [so chosen] shall be tested in accordance with the specifications.

Section 8.—In the first sentence change the phrase "in three consecutive yards" to read "in a specimen of three consecutive yards."

Section 10.—In the first sentence insert the word "specimen" after the word "tape."

Sections 12 and 13 (*a*).—Combine these two sections and change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 12. (*a*) The tape shall show tackiness, that is, ability to stick to itself after light contact has been made in the following combinations: (1) front to front, (2) back to back, and (3) back to front. [13. (*a*)] Two 8-in. specimens shall be cut from each sample roll, care being taken not to touch the surface to be tested with the hands or otherwise. One specimen shall be placed lightly on a clean horizontal surface, then the second placed evenly upon the first. No weight or pressure other than the weight of the specimen shall be applied to the tapes. The two specimens shall be picked up from one end and then stripped slowly from each other starting at the same end. Tackiness in at least two of the combinations (1), (2) and (3) specified [in Section 12] shall be such that the point of separation remains approximately in the same horizontal plane as the hands that pull the tape apart. *In the back to back combination the specimens shall show some indication of tackiness by the point of separation traveling along the tapes as the hands pull the tape apart.*

Reletter Paragraphs (*b*) and (*c*) of Section 13 as Paragraphs (*b*) and (*c*) of the revised Section 12, and renumber the remaining sections accordingly.

Section 15.—Renumber as Section 14 and change the first sentence from its present form: namely,

> The dielectric strength shall be determined by placing a tape specimen, which shall be free from pinholes, between two flat electrodes, $\frac{1}{4}$ in. in width by 4 in. in length and having square edges and rounded ends.

to read as follows:

> The dielectric strength shall be determined by placing a specimen approximately 6 in. in length between two flat electrodes $\frac{1}{4}$ in. in width by $4\frac{1}{4}$ in. in length. The edges shall be square and the ends rounded to $\frac{1}{8}$-in. radius cylinders whose axes are

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1139 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 985.

parallel to the contact faces of the electrode thus giving an area of contact with the surfaces of the tape of exactly ¼ in. in width by 4 in. in length.

Section 18.—Change from its present form: namely,

18. *Measurement of Thickness.*—The thickness shall be measured with a micrometer graduated to 0.001 in., having a circular foot 0.24 to 0.26 in. in diameter, and with a weight on the specimen of not less than 8 oz. nor more than 10 oz. Five measurements shall be made at random on a length of not less than 3 ft.

to read as follows:

17. *Measurement of Thickness and Width.*—The thickness of the tape shall be determined by means of a micrometer graduated to 0.001 in. and having a presser foot 0.25 in. ± 0.01 in. in diameter, exerting a total force of 9 oz. ± 0.1 oz. The load shall be applied by means of a weight. Five thickness and five width measurements shall be made at random in a length of not less than 3 ft. on each sample roll and the maximum, minimum and average of these five measurements shall be reported.

Section 19.—In the first sentence change the word "paraffined" to "paraffin" and add the phrase "or its equivalent" after the word "paper."

Section 23.—Change from its present form: namely,

23. If any sample roll fails, two additional rolls shall be taken from the lot it represents and shall be tested. If either of these two additional sample rolls fails, the lot represented by the rolls shall be rejected.

to read as follows:

22. (*a*) The purchaser reserves the right to reject any part of the shipment that does not comply with Sections 18 and 19.

(*b*) If the tape fails in any one test of those prescribed in these specifications, two additional rolls shall be selected and subjected to that test. If either of these two additional rolls fails, the lot represented by the test rolls shall be rejected.

(*c*) The manufacturer shall replace the rejected tape and shall pay freight charges for the return of such material.

Revision of Tentative Specifications and Tests for Rubber Insulating Tape (A.S.T.M. Designation: D 119 – 34 T):[1]

Section 12 (a).—Change the last sentence to read the same as is recommended in Section 6 (*a*) of the Tentative Specifications D 69 – 34 T above.

Section 16.—Change the first sentence to read the same as is recommended in Section 15 of the Tentative Specifications D 69 – 34 T above.

Section 19.—Change to read the same as is recommended in Section 18 of the Tentative Specifications D 69 – 34 T above.

Section 22.—Add the following as a new Paragraph (*a*), relettering the remaining paragraphs accordingly:

22. (*a*) The purchaser reserves the right to reject any part of the shipment that does not comply with Sections 10 and 11.

In the new Paragraph (*b*) change the phrase "submitted to that test" to read "subjected to that test."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1145 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 991.

REPORT OF COMMITTEE D-13

ON

TEXTILE MATERIALS

Committee D-13 on Textile Materials has held its two customary interim meetings since the 1934 annual meeting of the Society. The fall meeting was held at the Hotel Pennsylvania, New York City, on October 18 and 19, 1934, and the spring meeting at the Biltmore Hotel, Providence, R. I., on March 14 and 15, 1935. The number of members and guests in attendance at these meetings was 63 and 70, respectively. A third meeting will be held in June at Detroit, Mich., in conjunction with the annual meeting of the Society.

The Advisory Committee has approved the following changes in committee organization and chairmanships. Mr. R. H. Adams resigned as chairman of Section II on Cotton Yarns, of Subcommittee A-1, and Mr. F. S. Cobb as chairman of Section VIII on Sewing Threads, of Subcommittee A-1. Since there appeared to be little work ahead of Section VIII, it was deemed advisable to combine it with Section II, and to change the title of the latter section to "Cotton Yarns and Threads." Mr. A. C. Clifford was appointed chairman of the combined sections. The scope of Section V on Hose, Belt, and Numbered Duck, of Subcommittee A-1, has been enlarged as indicated by a change of its title to "Heavy Cotton Woven Fabrics." Subcommittee A-3 on Wool and Its Products was reorganized. Mr. Werner von Bergen was selected as chairman of Section I on Wool in place of Mr. G. E. Hopkins who is serving as chairman of the entire subcommittee. Two new sections were added, namely, Section III on Woolen and Worsted Yarns, Mr. Fred Noechel, chairman, and Section IV on Woolen and Worsted Fabrics, Mr. A. G. Ashcroft, chairman. Mr. H. A. Mereness was appointed as chairman of Subcommittee A-7 on Silk. The vacancy in the chairmanship of Section III on Humidity, of Subcommittee B-1, caused by the resignation of Mr. G. B. Haven, was filled by the appointment of Mr. R. H. Brown. Mr. A. G. Ashcroft was selected as chairman of the newly formed Subcommittee B-5 on Sampling, Presentation and Interpretation of Data. Mr. W. E. Emley resigned as editor of specifications and Mr. W. H. Whitcomb and Mr. H. J. Ball were appointed to serve as an Editorial Committee to handle all matters relating to the form of standards. It was voted that the Committee on Papers, composed of Mr. Dean Harvey, chairman, and Messrs. K. B. Cook and D. C. Scott, be made a regular subcommittee in the organization of Committee D-13.

The following appointments of members to represent the committee on Committee E-1 on Methods of Testing have been made: Mr. W. D. Appel to serve on the main committee in place of Mr. W. E. Emley, resigned; Mr. A. G. Ashcroft to serve on Technical Committee IX on Interpretation and Presentation of Data; and Mr. G. E. Hopkins to serve on the newly organized Technical Committee XI on Designation and Interpretation of Numerical Requirements. Mr. D. E. Douty has been appointed by the Executive Committee of the Society as a member of the Advisory Committee of Committee E-1.

Committee E-6 on Papers and Publications has authorized the publication annually, instead of triennially as heretofore, of the D-13 volume of A.S.T.M. Standards on Textile Materials. It has also assigned a limited amount of space in the pamphlet for the publication in full or condensed form of some of the papers presented before the committee. It is expected that these changes will greatly increase the value of this publication and result in a wider circulation of it. The new edition will be issued soon after the annual meeting and will contain all of the numerous and important changes that have been made in the standards since June, 1933.

The present membership of the committee is 162, of whom 72 are classified as producers, 46 as consumers, and 44 as general interest members.

RECOMMENDATIONS AFFECTING STANDARDS

The recommendations of the committee regarding standards and tentative standards under its jurisdiction are summarized below together with the analysis of the letter ballot on each item. Comments, where necessary, are made under the Activities of Subcommittees.

I. Proposed Tentative Standards.—The committee recommends for publication as tentative the following three new methods of test, as appended hereto:

Tentative General Methods of Test for Properties of Cotton Fibers;[1]
Tentative Method of Test for Shrinkage in Laundering of Silk and Rayon Woven Broad Goods;[2]
Tentative Method of Test for Strength of Rayon Woven Fabric When Wet.[3]

II. Proposed Revisions of Tentative Standards.—The committee is presenting revisions in the following tentative methods and definitions and recommends that, as revised, they be continued as tentative:

Tentative Method of Estimating Hard Scoured Wool in Wool in the Grease (**D 232 – 34 T**), revised as appended hereto;[4]
Tentative Specifications for Tolerances and Test Methods for Rayon (D 258 - 32 T), revised as given in Appendix I;
Tentative Definitions and Terms Relating to Textile Materials (D 123 - 34 T) revised as given in Appendix I;

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[1] See p. 1202.—ED. [2] See p. 1248.—ED. [3] See p. 1250 —ED. [4] See p. 1260 —ED.

Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (D 276 – 33 T), revised as given in Appendix I;
Tentative Specifications for Tolerances and Test Methods for Tubular Sleeving and Braids (D 354 – 32 T), revised as given in Appendix I;
Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T), revised as given in Appendix I; and
Tentative Specifications for Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T), revised as given in Appendix I.

III. Proposed Revisions of Standards.—The committee recommends, for publication as tentative, revisions of five of its present standards, as follows:

Standard General Methods of Testing Woven Textile Fabrics (D 39 – 34), revisions appended hereto;[1]
Standard Specifications for Textile Testing Machines (D 76 – 33), revised and rewritten in improved editorial form as appended hereto;[2]
Standard Specifications for Tolerances and Test Methods for Tire Cord, Woven and on Cones (D 179 – 33), revisions appended hereto;[3]
Standard Specifications for Tolerances and Test Methods for Hose Ducks and Belt Ducks (D 181 – 34), revisions appended hereto;[4] and
Standard Specifications for Tolerances and Test Methods for Cotton Sewing Threads (D 204 – 33), revisions appended hereto.[4]

IV. Adoption of Tentative Standards as Standard.—The committee recommends that the Tentative Specifications for Holland Cloth (D 376 – 34 T)[5] be approved for submission to letter ballot of the Society for adoption as standard.

V. Tentative Standards and Revisions Continued.—The committee recommends that all other tentative standards and tentative revisions of standards under its jurisdiction not specifically referred to under Activities of Subcommittees be continued as tentative for another year.

Subsequent to the 1934 annual meeting, the committee presented to the Society through Committee E-10 on Standards the following two new tentative specifications, also revisions of two tentative standards and tentative revisions of two standard specifications. These were accepted for publication[6] by Committee E-10 at a meeting held on August 22, 1934, and appear in the 1934 *Proceedings:*

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[1] See p. 1407.—Ed. [2] See p. 1200.—Ed. [3] See p. 1405.—Ed. [4] See p. 1406.—Ed.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1175 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1038.

[6] In submitting these recommendations to Committee E-10 on Standards, Committee D-13 reported the following results of the letter ballot vote of a total of 31 ballots returned from a committee membership of 157: Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T), 13 affirmative, 0 negative and 18 ballots marked "not voting"; Tentative Specifications for Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T), 14 affirmative, 0 negative and 17 ballots marked "not voting"; Tentative Specifications for Asbestos Roving (D 375 – 34 T), 12 affirmative, 0 negative and 19 ballots marked "not voting"; Tentative Method of Estimating Hard Scoured Wool in Wool in the Grease (D 232 – 34 T), 12 affirmative, 0 negative and 19 ballots marked "not voting"; Standard Specifications for Chafer Tire Fabrics (D 316 – 34), 16 affirmative, 0 negative and 15 ballots marked "not voting"; Standard Specifications for Asbestos Yarns (D 299 – 33), 12 affirmative, 0 negative and 19 ballots marked "not voting."

New Tentative Specifications for:

Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T)[1]
Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T)[1]

Revised Tentative Standards:

Specifications for Asbestos Roving (D 375 – 34 T)[1]
Method of Estimating Hard Scoured Wool in Wool in the Grease (D 232 – 34 T)[1]

Tentative Revisions of:

Standard Specifications for Chafer Tire Fabrics (D 316 – 34)[1]
Standard Specifications for Asbestos Yarns (D 299 – 33) in the form of new Tentative Specifications (D 299 – 34 T).[1]

Attention is called to the fact that extensive editorial changes have been made in many of the standards in order to bring their titles into closer conformity with Society practice, to change the sections on scope to agree with the changes in titles, and to include, where pertinent, a uniform definition for "tolerance" and for "direction of twist."

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 162 members; with the results shown in the accompanying Table I.

TABLE I.–ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirm-ative	Neg-ative	Ballots Marked "Not Voting"
I. PROPOSED TENTATIVE STANDARDS			
General Methods of Test for Properties of Cotton Fibers:			
Length and Length Distribution	21	1	29
Fineness	21	1	29
Immaturity Count	23	0	28
Strength	21	1	29
Method of Test for Shrinkage in Laundering of Silk and Rayon Woven Broad Goods	25	0	26
Method of Test for Strength of Rayon Woven Fabric When Wet[a]	23	3	34
II. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Method of Estimating Hard Scoured Wool in Wool in the Grease (D 232 – 34 T)	24	0	36
Specifications for Tolerances and Test Methods for Rayon (D 258 – 32 T)	25	1	34
Definitions and Terms Relating to Textile Materials (D 123 – 34 T)	47	0	4
Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (D 276 – 33 T)	40	2	18
Specifications for Tolerances and Test Methods for Tubular Sleeving and Braids (D 354 – 32 T)	18	0	42
Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T)	24	0	36
Specifications for Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T)	23	1	36
III. PROPOSED REVISIONS OF STANDARDS			
General Methods of Testing Woven Textile Fabrics (D 39 – 34)	35	1	15
Specifications for Textile Testing Machines (D 76 – 33)	41 48	2 0	8 12
Specifications for Tolerances and Test Methods for Tire Cord, Woven and on Cones (D 179 – 33)	23	1	36
Specifications for Tolerances and Test Methods for Hose Ducks and Belt Ducks (D 181 – 34)	25	0	35
Specifications for Tolerances and Test Methods for Cotton Sewing Threads (D 204 – 33)	32	1	27
IV. ADOPTION OF TENTATIVE STANDARD AS STANDARD			
Specifications for Holland Cloth (D 376 – 34 T)	18	1	41

[a] The classified vote on the Tentative Method of Test for Strength of Rayon Woven Fabric When Wet was as follows: Affirmative: 10 producers, 3 consumers, 10 general interests; negative: 0 producers, 1 consumer, 2 general interests.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. **34**, Part I, pp. 1178, 1181, 1169, 1184, 1275, 1172 (1934): also 1934 Book of A.S.T.M. Tentative Standards, pp. 1055, 1058, 1032, 1065, 1203, 1035.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee A-1 on Cotton and Its Products (K. B. Cook, chairman):

Section I on Cotton (R. W. Webb, chairman).—This section is presenting proposed Tentative General Methods of Test for Properties of Cotton Fibers, as appended hereto,[1] which embody the results of extensive investigations by the cotton fiber laboratories of the U. S. Bureau of Agricultural Economics in the development of methods for measuring certain properties of cotton fibers. The methods are divided into four main parts which deal respectively with the determination of the length and length distribution, fineness, immaturity count, and strength. Illustrations are included to show such special apparatus as is required and examples are given of the methods of recording, calculating and reporting the data. It is planned to encourage familiarity with the new methods by providing opportunities for comprehensive check tests on results obtained in different laboratories. Effort also will be made to stimulate interest in the work of the section on the part of cotton breeders and other agricultural workers in the United States, as well as technical workers in the field of home economics who are interested in the quality of consumer cotton products as inferred from the properties of the raw stock.

Section II on Cotton Yarns and Threads (A. C. Clifford, chairman).—This section recommends for publication as tentative a revision, as appended hereto,[2] of the Standard Specifications for Tolerances and Test Methods for Cotton Sewing Thread (D 204 - 33). This revision provides for the conditioning of samples before testing by exposure for a suitable length of time under standard atmospheric conditions. It improves the standard by giving recognition to the important effect of moisture on strength, yards per pound, and the calculated total yardage. The section is working on the development of a device to measure, conveniently and accurately, the total yardage of yarn or thread in a package under a condition of uniform and controlled tension. Further progress is reported on the compilation of data for the purpose of revising the present trade standards of yarn strength.

Section III on Light and Medium Cotton Woven Fabrics (R. T. Fisher, chairman).—This section believes there is no present advantage in retaining the detailed description of the shrinkage test procedure in the Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 - 34),[3] Sections 8 to 15, inclusive, and recommends, as an editorial change, that it be deleted. The procedure is given in full in the Standard General Methods of Testing Woven Textile Fabrics (D 39 - 34) to which reference is made in the former standard for all test procedures not otherwise specified. The section plans to see what can be done to harmonize the requirements of the Standard Cotton Textile Sales Note and Specification "G," sponsored by the Cotton Textile Institute and other trade organizations, with those contained in the standards of Committee D-13.

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[1] See p. 1202.—ED.
[2] See p. 1406.—ED.
[3] 1934 Supplement to Book of A.S.T.M. Standards, p. 187.

Section IV on Tire Fabrics (Martin Castricum, chairman).—This section recommends that the Tentative Specifications for Holland Cloth (D 376 – 34 T)[1] be adopted as standard. No further changes in the specifications are contemplated at present and, in their present form, they embody the benefits of all constructive criticisms received since they were first issued in 1933 and revised in 1934. The section also recommends for publication as tentative a revision, as appended hereto, of the Standard Specifications for Tolerances and Test Methods for Tire Cord, Woven and on Cones (D 179 – 33), which provides for the use of an empirical dial in place of a calibration scale or chart to correct for machine inaccuracies. Section IV has continued its study of the accuracy of calibration of horizontal testing machines by conducting an inter-laboratory check test. The test included twenty machines in ten different laboratories and used six different sizes of soft annealed copper wire as the standard test material. The results show a significant difference in calibration levels and disclose a real need for an accurate, convenient and dependable method of calibration for such machines. Further study of the problem is to be made, and the assistance of Section II on Machines, of Subcommittee B-1 has been asked. The section plans a thorough editorial revision of the Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (D 122 – 33), Standard Specifications for Chafer Tire Fabrics (D 316 – 34), and Standard Specifications for Enameling Duck for the Tire Industry (D 336 – 33), and will consider their possible combination into one standard.

Section V on Heavy Cotton Woven Fabrics (B. L. Whittier, chairman).—This section is presenting for publication as tentative a revision, as appended hereto,[2] of the Standard Specifications for Tolerances and Test Methods for Hose Ducks and Belt Ducks (D 181 – 34) for the purpose of clarifying the method of determining the width of the fabric and the specified weight of a full roll. The section is planning a revision of the Standard Specifications for Tolerances for Numbered Cotton Duck (D 230 – 27) to include methods of test for numbered ducks, army ducks and similar heavy fabrics, and also changes in the present tolerances.

Section VI on Narrow Fabrics (F. S. Mapes, chairman).—This section recommends a revision, as given in Appendix I, of the Tentative Specifications for Tolerances and Test Methods for Tubular Sleeving and Braids

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1175 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1038.

[2] See p. 1406.—ED.

(D 354 – 32 T), in regard to the determination of the wall thickness. It selects the Method B procedure described in the Tentative Methods of Test for Thickness of Solid Electrical Insulation (D 374 – 34 T), prepared by Committee D-9 on Electrical Insulating Materials. The effect is to change the size of the anvil faces, more carefully prescribe the procedure, and set up micrometer requirements which were not stipulated heretofore. The section again recommends that the Tentative Specifications for Tolerances and Test Methods for Silk and Cotton Tapes (D 259 – 31 T) be continued as tentative to give further time for the consideration of other methods of thickness measurement than those now specified. The section is planning a revision of and addition to other standards under its jurisdiction to meet comments and criticisms that have been suggested by the Sectional Committee on Electrical Insulating Materials, functioning under the procedure of the American Standards Association. If the section finds that it will be assured of sufficient interest and support, it will consider the preparation of methods of test for typewriter and similar ribbons.

Subcommittee A-2 on Rayon and Its Products (A. M. Tenney, chairman):

Section I on Rayon (A. M. Tenney, chairman).—This section is recommending an extensive revision of the Tentative Specifications for Tolerances and Test Methods for Rayon (D 258 – 32 T) in the form as appended hereto.[1] Those sections of the methods which deal with identification have been completely revised and rewritten in order to keep the methods for distinguishing between the types of rayon abreast of new developments in laboratory technique. To this end, useful stain tests and microscopic examination of cross-sections and lateral surfaces have been added, together with an extensive set of new photomicrographs as reference standards. In the method of twist determination, fixed values for the tension weight for certain ranges of yarn number replace the present stipulation of a weight which varies directly with the denier. This is believed to be more practical. The section expects to give consideration during the coming year to a further revision and improvement of these specifications and to the subject of performance tests.

Section II on Rayon Fabrics (Alexis Sommaripa, chairman).—This section is proposing for publication, as appended hereto,[2] a new Tentative Method of Test for Strength of Rayon Woven Fabric When Wet. It sets forth a method for determining the dry and the wet strength of a fabric, and their correction to a comparable basis. This test was originated to supply information as to one of the effects of laundering upon rayon fabrics. At a joint meeting with Subcommittee A-7 on Silk, this section approved a shrinkage test for silk and rayon broad goods, further reference to which is made under the activities of Subcommittee A-7. At the fall meeting the section held a very well attended session at which a paper was presented by Mr. D. R. Craig and Mr. P. F. Lazarsfeld reporting the results of an extensive study they had made on the acceptance and rejection of rayon by eight hundred women consumers of products made from this material. Progress is reported upon the development of an unraveling or fraying test for rayon fabrics and it is expected that this will be ready for presentation in the near future.

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[1] See p. 1233.—ED.
[2] See p. 1250.—ED.

Subcommittee A-3 on Wool and Its Products (G. E. Hopkins, chairman):

Recommendations regarding standards reported under the following sections of this subcommittee have been submitted to the membership of the entire subcommittee and have received its approval:

Section I on Wool (Werner von Bergen, chairman).—This section is presenting an extensive revision of the Tentative Method of Estimating Hard Scoured Wool in Wool in the Grease (D 232 – 34 T) in the form as appended hereto.[1] The extraction method in particular has been revised to bring it into closer accord with the Code method and to improve its accuracy. As a further measure of the completeness of the scouring operation, a requirement for pH value has been added. Equations have also been inserted in the method to indicate clearly how the results of an analysis shall be calculated on either a dry or a standard regain basis. The section is actively engaged in a study of methods of classification of wool fibers and hopes to present some recommendations during the coming year.[2]

Section II on Felt (J. F. Marshall, chairman).—The work of this section has been concentrated upon the preparation of methods of test for felt in order to meet a request from the United States Felt Manufacturers Institute for standard test methods. The section reports that a tentative standard is nearly ready for presentation.

Section III on Woolen and Worsted Yarns (Fred Noechel, chairman).—This section is recommending identical revisions of two tentative standards, namely, the Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T) and the Tentative Specifications for Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T), as indicated in Appendix I. The changes in the extraction method and the equations which have been added are of the same character and are made for the same reasons as stated above under Section I on Wool. For purposes of standardization and simplification, the section is eliminating from the tentative specifications any reference to the commonly accepted trade systems of denoting yarn number, and is recommending the use of the Typp system. This is a new plan, based upon the number of thousands of yards per pound, which was proposed by Mr. E. D. Fowle in the April 23,

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[1] See p. 1260.—ED.

[2] Subsequent to the annual meeting Committee D-13 presented to the Society new Tentative Methods of Test for Fineness of Wool, see Editorial Note, p. 446.—ED.

1932, issue of *Textile World*. To facilitate conversions from one system to another reference will be made in both specifications to the yarn number conversion table which appears in Appendix II. The section has under consideration further improvements in and amendments to both tentative specifications.[1]

Section IV on Woolen and Worsted Fabrics (A. G. Ashcroft, chairman).—This section has been actively engaged in preparing test methods for pile floor coverings[1] and a tentative standard is nearly ready for presentation. The section is developing a wear test procedure for the same type of material and is planning to prepare standard test methods for woolen and worsted fabrics.

Subcommittee A-4 on Asbestos and Its Textile Products:

Section I on Asbestos Textiles (J. M. Weaver, chairman).—For purposes of record an explanation is given here of the tentative revision in the Standard Specifications for Asbestos Yarns (D 299 – 33), which was accepted in the form of new tentative specifications by Committee E-10 on Standards as noted above under Recommendations Affecting Standards. Experience in the use of the standard disclosed the need for an addition to the definition of asbestos yarn, for a formula for calculating the shrinkage of a plied yarn due to twisting, and the inclusion of a 22-count yarn in the yardage table. To meet the full range of present-day demands the number of grades was increased and corresponding changes were made in the percentages of asbestos content. The specifications were made more complete by adding requirements for tensile strength and the method of its determination. For the coming year the section is planning important revisions of the Standard Specifications and Test Methods for Asbestos Tape for Electrical Purposes (D 315 – 33) to include a test method for making magnetic iron determinations in asbestos textiles, for the measurement of electrical resistivity, and specifications for 10-mil tape.

Subcommittee A-7 on Silk (H. A. Mereness, chairman):

Subcommittee A-7 is presenting for publication, as appended hereto,[2] a new Tentative Method of Test for Shrinkage in Laundering of Silk and Rayon Woven Broad Goods. It contains a clearly defined test procedure developed for the purpose of supplying the information indicated by the title, and for use for general technical purposes. The section has nearly completed a test method for the determination of slippage in the above-mentioned fabrics and expects to present it in the near future. It is also collaborating with Subcommittee B-4 on Bleaching, Dyeing and Finishing on the development of a method to determine the dye fastness to washing of silk and rayon broad goods.

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[1] Subsequent to the annual meeting Committee D-13 presented to the Society revisions of the Tentative Methods for Woolen Yarns and Worsted Yarns, and new Tentative Methods of Testing Pile Floor Covering, see Editorial Note, p. 446.—ED.

[2] See p. 1248.—ED.

Subcommittee B-1 on Methods and Machines (W. D. Appel, chairman):

Section I on Methods (W. D. Appel, chairman).—This section is recommending a modification of the revision,[1] first published as tentative in 1933, of the Standard General Methods of Testing Woven Textile Fabrics (D 39 - 34), as appended hereto.[2] Its purpose is to simplify and clarify the procedure for the measurement of elongation. The section also recommends a revision of the Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (D 276 - 33 T) as indicated in Appendix I. This revision is largely editorial in its character and is for the purpose of clarifying certain sections of the methods. The section plans to secure some new and better photomicrographs to supplant those now appearing as reference plates in connection with these tentative methods. The section reports progress in the thorough review and revision it is making of the Standard General Methods of Testing Woven Textile Fabrics (D 39 - 34), and expects to have certain changes ready to submit during the coming year. It also plans a further study of the identification methods referred to above.

Section II on Machines (H. J. Ball, chairman).—This section is recommending for publication as tentative a revision of the Standard Specifications for Textile Testing Machines (D 76 - 33) in the form of new tentative specifications, as appended hereto,[3] which are intended to replace the present specifications when adopted as standard. Experience has shown the need for the changes, the important items of which are the recognition of the constant specimen-rate-of-load type of testing machine as an approved tester, of the flat grip jaws for individual strand tests, and of a tolerance in the speed of the pulling jaw in the pendulum type of machine. All reference to alignment pins and to the backlash in the dial pointer has been deleted. The section plans to give further consideration to the matter of single strand jaws and to calibration methods. A paper was presented before the section by Mr. H. G. Romig, on behalf of Subcommittee B-5 on Sampling, Presentation and Interpretation of Data, which gave an excellent statistical analysis of the data from the inter-laboratory calibration check tests on horizontal testing machines referred to above under Section IV on Tire Fabrics of Subcommittee A-1. The section is working upon specifications for diaphragm bursting testers.

Subcommittee B-2 on Nomenclature and Definitions (A. L. Brassell, chairman):

This subcommittee recommends a revision of the Tentative Definitions and Terms Relating to Textile Materials (D 123 - 34 T) as indicated in Appendix I. The important item is the revision of the definition of "direction of twist" by the adoption of the "S" and "Z" notation proposed by Mr. E. D. Fowle in the August, 1934, issue of *Textile World*. Committee D-13 feels that this action is an important contribution to the settlement of that much discussed question as to what is right-hand and left-hand twist, and the revision was adopted by a large affirmative vote and without a dissenting vote. This new definition will also be inserted, as an editorial change, in all the standards of the committee in which reference to direction of twist is made, and will either replace the definition which formerly appeared there or be added to the standard as new material. The section is at work upon the plan to separate the terms in the above-mentioned standard into two lists in the manner and for the purposes set forth in the 1934 report[1] of the committee.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1276 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1204.

[2] See p. 1407.—ED.

[3] See p. 1200.—ED.

Subcommittee B-4 on Bleaching, Dyeing, and Finishing (W. M. Scott, chairman):

This subcommittee reports that it is practically ready to present a test method for fastness to laundering and domestic washing of (1) dyed or printed silk or rayon, and (2) dyed or printed cotton. After a study of the results of further comparative check tests, a method for determining the amount of sizing and finishing materials in cotton fabrics will be completed and presented early in the coming year. Work is in progress upon a test for the fastness of dyed fabrics to light. The section plans to revise the Tentative Methods of Test for Small Amounts of Copper and Manganese in Textiles (D 377 – 33 T), and to work upon the development of a method for evaluating the detergency of soaps. It reports a temporary suspension of its plans for methods for determining the presence of oxycellulose and hydrocellulose in bleached cotton fabrics, and for testing the waterproofness of fabrics.

Subcommittee B-5 on Sampling, Presentation and Interpretation of Data (A. G. Ashcroft, chairman):

This newly-formed subcommittee has held one formal meeting during the year for organization purposes and to discuss plans for its future work. Interest in this new phase of activity by Committee D-13 is evidenced by the rapid growth of this subcommittee, without particular solicitation, to a present membership of fifteen. The subcommittee reports that its work will be primarily promotional and educational rather than the development of standards. It plans to develop contacts with other subcommittees and sections which may be in need of assistance in the statistical attacks upon their own research or test data. It is considering the possibility of the compilation of data on the variability of various textile materials with a view to suggesting methods of setting up limits and tolerances more in keeping with statistical methods than those in use at present. The subcommittee has sponsored two papers presented during the year which illustrated the use of statistical methods in connection with testing and research. One paper, the title of which is given in full under Subcommittee B-6 on Papers, was presented at the fall meeting by Mr. I. J. Saxl of the Waypoyset Manufacturing Co., and discussed by Mr. H. F. Dodge of the Bell Telephone Laboratories. The second paper was prepared under the direction of Mr. H. F. Dodge and presented by Mr. H. G. Romig, as reported above under Section II on Machines, of Subcommittee B-1.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 540 (1934).

Subcommittee B-6 on Papers (Dean Harvey, chairman):

The Subcommittee on Papers, which has functioned for many years, has this year been formally placed in the organization of Committee D-13 as indicated above. The subcommittee has arranged for the presentation of the following papers at the interim meetings of Committee D-13:

"Some Observations from a Study of Wool Flannels, Serges and Gabardines," by Ethel L. Phelps;
"The Principle of Probability in the Evaluation of Testing Results," by I. J. Saxl;
"Determination of Twist in Single Wool and Worsted Yarns," by Fred Noechel;
"The Flat Bundle Test for Tensile Strength of Fibers," by G. F. Crowley, and
"Positive Control of Stretch in Cotton and Rayon Yarns During Slashing; Effects on Weaving and Finishing," by K. B. Cook.

This report has been submitted to letter ballot of the committee, which consists of 162 members; 60 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. J. BALL,
Chairman.

W. H. WHITCOMB,
Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee D-13 on Textile Materials presented to the Society on August 22, 1935, through Committee E-10 on Standards the following additional recommendations:

Proposed Tentative Methods of:
Testing Pile Floor Covering
Test for Fineness of Wool

Proposed Revision of Tentative Methods of:
Testing and Tolerances for Woolen Yarns (D 403 – 35 T)
Testing and Tolerances for Worsted Yarns (D 404 – 35 T)

The above recommendations were accepted by Committee E-10 and the new and revised tentative methods appear respectively on pp. 1229, 1256, 1263 and 1268.

APPENDIX I

PROPOSED REVISIONS IN TENTATIVE STANDARDS FOR TEXTILE MATERIALS

In this appendix are given the proposed revisions in certain specifications and methods of test referred to in the body of the report. In connection with each title is given the reference to the publication in which each standard appears in its present form.

Revision of Tentative Specifications for Tolerances and Test Methods for Rayon (A.S.T.M. Designation: D 258 - 32 T):[1]

Sections 3 to 6.—Delete the present Identification Methods described in these sections and substitute the procedures appended hereto[2] as Sections 4 to 9, inclusive, renumbering the present sections accordingly.

Section 10.—Renumber this section as Section 3 and change the definition of the term "Twist, Direction of" from its present form to read the same as is recommended in the Tentative Definitions D 123 - 34 T above.

Sections 21 and 22.—Delete these sections which cover an alternate method for the determination of size or yarn number, renumbering the remaining sections accordingly.

Section 32.—Change the twist test from its present form: namely,

> 32. The twist shall be determined on any standard twist tester with jaws set 10 in. apart. The yarn shall be clamped in the jaws under a definite tension by attaching weights. The tension to be used shall approximate a value to be determined by the following formula:
>
> $$\text{Tension in grams} = \frac{\text{Specified denier}}{30}$$
>
> *Example.*—The weight for 150 denier rayon would be $\frac{150}{30} = 5$ g.

to read as follows:

> 26. The twist shall be determined on any standard twist tester with jaws set 10 in. apart. The yarn shall be clamped in the jaws under a definite tension by attaching a weight. The tension weight to be used shall be as follows:
>
> 10 g. for yarns 75 denier and finer;
> 20 g. for yarns from 150 denier to 75 denier, and
> 30 g. for yarns coarser than 150 denier.
>
> NOTE.—Where yarn is unraveled from cloth for test, it is recommended that the tension weight specified be increased by 10 g. in each classification.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 934 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 1041.

[2] See p. 1235.—ED.

Revision of Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 34 T):[1]

Cordage.—Omit the definition of this term, which reads as follows:

Cordage.—A term used in a collective sense to include all sizes and varieties of twines, cords, ropes and cables of textile materials.

Kapok.—Omit the third and fourth words, namely, "or down," making the first clause read as follows, the balance of the definition remaining as at present: "Stuffing fiber composed of single cells.........."

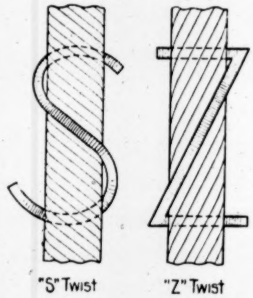
Twist, Direction of.—Change from its present form: namely,

Twist, Direction of.—In the case of yarn or cord held in a horizontal position and fixed at the left end, if the twist is taken out by turning to the right, or clockwise, when viewed from the right end, it is right twist, and, if the twist is taken out by turning to the left, or counter-clockwise, when viewed from the right end, it is left twist; that is, the yarn or cord has right twist if, when it is held vertically, the spirals or twists are seen to incline upward to the right, and has left twist if the spirals or twists are seen to incline upward to the left.

NOTE.—This definition is used by the cotton and wool industries. Due to trade custom, the opposite of this definition is used by the sewing thread, silk, and rayon industries.

to read as follows:

Twist, Direction of.—A yarn or cord has "S" twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and "Z" twist if the spirals conform in slope to the central portion of the letter "Z."



Revision of Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 - 33 T):[2]

Section 3.—Under Methods for the Quantitative Analysis of Textiles change the last sentence of Paragraph (*a*) to read as follows by the addition of the italicized word and the omission of the words in brackets:

When it is necessary to modify the procedure in order to completely remove non-fibrous constituents, the analyst shall make sure that purified samples of the fibers under consideration do not lose weight when subjected to the same treatment

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1186 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1080.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 931 (1933); also 1934 Book of A.S.T.M. Tentative Standards, p. 1067.

[and the]. *Ordinarily,* samples shall [then] be analyzed according to Paragraphs (*b*) to (*d*).

Change the last sentence of Paragraph (*c*) to read as follows by the addition of the italicized words and the omission of those in brackets:

It shall then be washed [while squeezing] by [alternate] *repeated* immersion in hot distilled water, *squeezing between each immersion.*

Change Paragraph (*d*) from its present form to read as follows:

(*d*) The specimen shall then be immersed in a 3 to 5 per cent aqueous solution of a starch and protein-solubilizing enzyme preparation at 122 F. (50 C.). It shall be squeezed while immersed, removed and squeezed again, and this procedure repeated at least three times. The purpose is to insure thorough wetting of the fibers by the enzyme solution. The enzyme solution shall then be maintained at 122 to 140 F. (50 to 60 C.), or the optimum temperature range for the particular enzyme used, and the specimen kept immersed in it for 1 hr. A shorter time is permissible if sizing is removed in the shorter time. Fifteen minutes is sufficient for some textiles. The specimen shall then be rinsed twelve times in fresh portions of hot distilled water, squeezing after each rinse. Thorough rinsing is necessary in order to remove china clay from heavily filled fabrics. The enzyme treatment and rinsing may be carried out in a Launder-Ometer or similar device if desired. The rinsed specimen shall then be dried at 221 to 230 F. (105 to 110 C.) to constant weight. This gives the weight of dry fiber, weight *C*.

Section 5.—Change Paragraph (*a*) from its present form to read as follows:

5. (*a*) The fibers constituting the residue from the test for cellulose-acetate rayon (Section 4) shall be cut to lengths of about 2 to 4 mm. They shall be agitated vigorously for 1 hr. in 200 ml. of a clear aqueous solution of calcium thiocyanate of specific gravity 1.20 to 1.21 at a temperature of 158 F. (70 C.) made just acid to litmus with acetic acid, and maintained at a temperature of 158 ± 4 F. (70 ± 2.2 C.). Precautions shall be taken to prevent evaporation from the solution with consequent concentration of the thiocyanate. The fibers which are not dissolved shall be collected in a small Buchner funnel, Gooch crucible, or bitumen filter, preferably with the aid of suction. When a good pad of fibers has formed on the filter, the hot mother liquor shall be poured through a second time to recover all fibers on the pad. The fibers shall then be agitated for 5 min. in a fresh 200-ml. portion of the thiocyanate solution. The filtration shall be repeated and the fibers washed with hot distilled water until free from thiocyanate. They shall be dried to constant weight, weight *E*.

Section 6.—Change Paragraph (*a*) from its present form to read as follows:

6. (*a*) The fibrous residue from the test for silk (Section 5) shall be pulled apart or cut up. It shall be treated in accordance with the procedure in Section 5 except that the acid solution of calcium thiocyanate shall be of specific gravity 1.35 to 1.36 at a temperature of 158 F. (70 C.). The weight of the dried residue from this treatment is weight *F*.

Section 7.—Change Paragraph (*a*) from its present form to read as follows:

7. (*a*) The residue from the test for regenerated cellulose rayon (Section 6), which contains cotton and wool, shall be immersed for 10 min. in a boiling solution of aluminum chloride containing 5 g. of $AlCl_3$ (or 9 g. of the hydrated salt $AlCl_3 \cdot 6H_2O$) per 100 ml. of water. It shall be removed from the solution and after allowing the excess liquid to drain off (the specimen shall not be squeezed), it shall be heated in an oven at 221 to 230 F. (105 to 110 C.) until the cotton has become brown in color and brittle (usually 2 hr. is sufficient). The specimen shall be placed on a 100-mesh screen and rubbed against the screen with sufficient pressure to powder the carbonized cellulose and pass it through. The residual fibers (wool) shall be placed in a suitable container, preferably a 250-ml. beaker. The material which passed through the screen shall be screened again to recover any wool fibers which passed through. The wool shall be agitated with about 100 ml. of dilute hydrochloric acid solution (1 part by volume of the concentrated laboratory reagent diluted with 9 parts of distilled water), collected as a pad (see Section 5 (*a*)), washed with distilled water until free from chlorides, and dried at 221 to 230 F. (105 to 110 C.) to constant weight, weight *G*.

Revision of Tentative Specifications for Tolerances and Test Methods for Tubular Sleeving and Braids (A.S.T.M. Designation: D 354 – 32 T):[1]

Section 9.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

9. The thickness of the wall shall be determined by inserting a mandrel of the nominal inside diameter of the sleeving or braid in the sample and measuring the outside diameter [with a hand micrometer having anvil faces $\frac{7}{16}$ to $\frac{1}{2}$ in. in diameter]. *Such measurements shall be made in accordance with Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374-34 T) of the American Society for Testing Materials.* By subtracting the mandrel diameter from the [overall measurement] *outside diameter* and dividing *the difference* by two, the wall thickness is [secured] *determined.*

Revision of Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (A.S.T.M. Designation: D 403 – 34 T):[2]

Section 3.—Add a new Paragraph (*c*) to read as follows:

(*c*) *Yarn Number.*—The number of a woolen yarn shall be the number of thousands of yards per pound (Typp System).[a]

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[a] See the Yarn-Number Conversion Table which appears as Appendix II to this report.

Section 9.—Change from its present form to read as follows:

9. (*a*) *Free Fat.*—Three 10-g. samples (approximate) shall be extracted separately in a Soxhlet apparatus for 20 extractions with alcohol-free ethyl ether (Note). In the bottom of the Soxhlet apparatus there shall be lightly placed a thin layer of cotton, previously extracted with ethyl ether, as a filter covering the opening of the siphon tube. The ether then shall be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is free fat.

NOTE.—C.p. carbon tetrachloride shall be substituted for ethyl ether for Code work.

(*b*) *Soap Fat.*—The samples from which the free fat has been removed (Paragraph (*a*)) shall be extracted in a Soxhlet apparatus for 12 extractions with neutral

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part I, p. 942 (1932); also 1934 Book of A.S.T.M. Tentative Standards, p. 1049.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1178 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1055.

95 per cent alcohol. The alcohol shall then be evaporated from the extract. After adding 25 to 30 ml. of 0.1 N HCl this shall be boiled and cooled. The solution shall then be shaken with an equal volume of neutral ether and decanted. This shall be repeated twice. The three ether extracts shall be combined and washed once by shaking with an equal volume of distilled water and then decanted. The ether shall then be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is soap fat.

(*c*) *Weight, Oven-Dry Extracted Wool.*—The extracted wool (Paragraph (*b*)) shall be dried to constant weight at 212 to 221 F. (100 to 105 C.).

(*d*) *Calculations.*—The percentage of free fat and of soap fat may be calculated on a dry or a standard regain basis by the following formulas:

$$\text{Free Fat (dry basis), per cent} = \frac{F \times 100}{W + F + S}$$

$$\text{Soap Fat (dry basis), per cent} = \frac{S \times 100}{W + F + S}$$

$$\text{Free Fat (standard regain basis), per cent} = \frac{F \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

$$\text{Soap Fat (standard regain basis), per cent} = \frac{S \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

where F = the weight of free fat
S = the weight of soap fat
W = the weight of oven-dry extracted wool

(*e*) Three samples shall be tested from each case or beam of yarn. If the three determinations do not check, or if the average results fail to conform to the specification requirements, three additional samples shall be tested from the same case or beam from which the original samples were taken.

Revision of Tentative Specifications for Tolerances and Test Methods for Worsted Yarns (A.S.T.M. Designation: D 404 – 34 T):[1]

Section 3.—Reletter Paragraph (*a*) as Paragraph (*c*) and change this paragraph from its present form: namely,

> 3. (*a*) *Yarn Number.*—The size of worsted yarn shall be specified in terms of the number of 560-yd. hanks per pound (English System).

to read as follows, relettering the remaining paragraphs accordingly:

> (*c*) *Yarn Number.*—The number of a worsted yarn shall be the number of thousands of yards per pound (Typp System).[a]

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[a] See the Yarn-Number Conversion Table which appears as Appendix II to this report.

Section 9.—Change from its present form to read exactly like the new Section 9 that is being recommended for inclusion in the Tentative Specifications D 403 – 34 T, above.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1181 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1058.

APPENDIX II

YARN NUMBER CONVERSION TABLE

Note.—The column headed "linen" also serves for other bast-fiber yarns and for the woolen cut.

The grain weight for 12 yd. can be easily obtained by moving the decimal point one place to the left in the grain weight for 120 yd.

The grain weight for the following lengths can be easily obtained from the grain weight for 100 yd.

- **(a) For 50 yd., by dividing by 2.**
- **(b) For 20 yd., by dividing by 5.**
- **(c) For 25 yd., by dividing by 4.**
- **(d) For 12½ yd., by dividing by 8.**
- **(e) For 10 yd., by dividing by 10.**
- **(f) For 1 yd., by dividing by 100.**

In the metric system 496 yd. per pound is the American equivalent of 1 kilometer per kilogram.

Runs, 1600 yd. per lb.	Cotton, 840 yd. per lb.	Worsted, 560 yd. per lb.	Linen, 300 yd. per lb.	Yards per lb.	Grains per 120 yd.	Grains per 100 yd.	Drams per 1000 yd.	Denier 0.05 g. per 450 meters	Metric, 496 yd. per lb.
0.125	0.24	0.36	0.67	**200**	4200	3500	1280	22 323	0.4
0.19	0.36	0.54	**1.**	**300**	2800	2333⅓	853⅓	14 882	0.6
0.25	0.48	0.71	1.33	**400**	2100	1750	640	11 161	0.8
0.35	0.67	**1.**	1.87	**560**	1500	1250	457.14	7 972	1.1
0.375	0.71	1.07	**2.**	**600**	1400	1166⅔	426.66	7 441	1.2
0.50	0.95	1.43	2.67	**800**	1050	875	320	5 581	1.6
0.525	**1.**	1.50	2.80	**840**	1000	833⅓	304.76	5 315	1.7
0.56	1.07	1.61	**3.**	**900**	933.3	777.8	284.44	4 961	1.8
0.63	1.19	1.79	3.33	**1 000**	840	700	256	4 465	2.
0.70	1.33	**2.**	3.73	**1 120**	750	625	228.57	3 986	2.3
0.75	1.43	2.14	**4.**	**1 200**	700	583.3	213.33	3 720	2.4
0.88	1.67	2.50	4.67	**1 400**	600	500	182.86	3 189	2.8
0.94	1.79	2.68	**5.**	**1 500**	560	466.7	170.67	2 976	3
1.	1.90	2.86	5.33	**1 600**	525	437.5	160	2 790	3.2
1.05	**2.**	**3.**	5.60	**1 680**	500	416.7	152.38	2 657	3.4
1.13	2.14	3.21	**6.**	**1 800**	466.7	388.9	142.22	2 480	3.6
1.25	2.38	3.57	6.67	**2 000**	420	350	128	2 232	4
1.31	2.50	3.75	**7.**	**2 100**	400	333.3	121.90	2 126	4.2
1.38	2.62	3.93	7.33	**2 200**	381.8	318.2	116.36	2 029	4.4
1.40	2.67	**4.**	7.47	**2 240**	375	312.5	114.28	1 993	4.5
1.50	2.86	4.29	**8.**	**2 400**	350	291.7	106.67	1 860	4.8
1.57	**3.**	4.50	8.40	**2 520**	333.3	277.8	101.59	1 772	5.1
1.63	3.10	4.64	8.67	**2 600**	323.1	269.2	98.46	1 717	5.2
1.69	3.21	4.82	**9.**	**2 700**	311.1	259.3	94.81	1 654	5.4
1.75	3.33	**5.**	9.50	**2 800**	300	250	91.43	1 595	5.6
1.88	3.57	5.36	**10.**	**3 000**	280	233.3	85.33	1 488	6.1
2.	3.81	5.72	10.67	**3 200**	262.5	218.7	80	1 395	6.5
2.06	3.93	5.89	**11.**	**3 300**	254.5	212.1	77.58	1 353	6.7
2.10	**4.**	**6.**	11.20	**3 360**	250	208.3	76.19	1 329	6.8
2.13	4.05	6.07	11.33	**3 400**	247.1	205.9	75.29	1 313	6.9
2.25	4.28	6.43	**12.**	**3 600**	233.3	194.4	71.11	1 240	7.3
2.26	4.33	6.50	12.13	**3 640**	230.8	192.3	70.33	1 227	7.3
2.36	4.50	6.75	12.60	**3 780**	222.2	185.2	67.72	1 181	7.6
2.38	4.52	6.79	12.67	**3 800**	221.1	184.2	67.37	1 175	7.7
2.44	4.64	6.96	**13.**	**3 900**	215.4	179.5	65.64	1 145	7.9
2.45	4.67	**7.**	13.07	**3 920**	214.3	178.6	65.30	1 139	7.9
2.50	4.76	7.14	13.33	**4 000**	210	175	64	1 116	8.1
2.54	4.83	7.25	13.53	**4 060**	206.9	172.4	63.05	1 100	8.2
2.63	**5.**	7.50	**14.**	**4 200**	200	166.7	60.95	1 063	8.5
2.71	5.17	7.75	14.47	**4 340**	193.5	161.3	58.99	1 029	8.8
2.75	5.24	7.86	14.67	**4 400**	190.9	159.1	58.18	1 015	8.9
2.76	5.25	7.88	14.70	**4 410**	190.5	158.7	58.05	1 012	8.9
2.80	5.33	**8.**	14.93	**4 480**	187.5	156.3	57.14	997	9.
2.81	5.36	8.04	**15.**	**4 500**	186.7	155.6	56.89	993	9.1
2.88	5.48	8.21	15.33	**4 600**	182.6	152.2	55.65	971	9.3
2.89	5.50	8.25	15.40	**4 620**	181.8	151.5	55.41	966	9.3
2.97	5.67	8.50	15.87	**4 760**	176.5	147.1	53.78	938	9.6
3.	5.72	8.57	**16.**	**4 800**	175	145.8	53.33	930	9.7
3.02	5.75	8.63	16.10	**4 830**	173.9	144.9	53	924	9.7
3.06	5.83	8.75	16.33	**4 900**	171.4	142.9	52.24	911	9.9
3.13	5.95	8.93	16.67	**5 000**	168	140	51.20	893	10.1
3.15	**6.**	**9.**	16.80	**5 040**	166.7	138.9	50.79	886	10.2
3.19	6.07	9.11	**17.**	**5 100**	164.7	137.2	50.19	875	10.3
3.24	6.17	9.25	17.27	**5 180**	162.2	135.1	49.42	862	10.4
3.25	6.19	9.29	17.33	**5 200**	161.5	134.6	49.23	859	10.5
3.28	6.25	9.38	17.50	**5 250**	160	133.3	48.76	850	10.6
3.32	6.33	9.50	17.73	**5 320**	157.9	131.6	48.12	839	10.7
3.38	6.43	9.64	**18.**	**5 400**	155.6	129.6	47.40	827	10.9
3.41	6.50	9.75	18.20	**5 460**	153.8	128.2	46.89	818	11
3.50	6.67	**10.**	18.67	**5 600**	150	125	45.71	797	11.3

Courtesy of *Textile World*

YARN NUMBER CONVERSION TABLE (*Continued*)

Runs, 1600 yd. per lb.	Cotton, 840 yd. per lb.	Worsted, 560 yd. per lb.	Linen, 300 yd. per lb.	Yards per lb.	Grains per 120 yd.	Grains per 100 yd.	Drams per 1000 yd.	Denier 0.05 g. per 450 meters	Metric, 496 yd. per lb.
3.54	6.75	10.13	18.90	**5 670**	148.1	123.5	45.15	787	11.4
3.56	6.79	10.18	**19.**	**5 700**	147.4	122.8	44.91	783	11.5
3.63	6.90	10.36	19.33	**5 800**	144.8	120.7	44.14	770	11.7
3.67	**7.**	10.50	19.60	**5 880**	142.9	119	43.54	759	11.9
3.75	7.14	10.71	**20.**	**6 000**	140	116.7	42.67	744	12.1
3.81	7.25	10.88	20.30	**6 090**	137.9	114.9	42.04	733	12.3
3.85	7.33	**11.**	20.53	**6 160**	136.4	113.6	41.56	725	12.4
3.88	7.38	11.07	20.67	**6 200**	135.5	112.9	41.29	720	12.5
3.94	7.50	11.25	**21.**	**6 300**	133.3	111.1	40.63	709	12.7
4.	7.62	11.43	21.33	**6 400**	131.2	109.4	40	698	12.9
4.03	7.67	11.50	21.47	**6 440**	130.4	108.5	39.75	693	13
4.07	7.75	11.63	21.70	**6 510**	129	107.2	39.32	686	13.1
4.13	7.86	11.79	**22.**	**6 600**	127.3	106.1	38.79	676	13.3
4.20	**8.**	**12.**	22.40	**6 720**	125	104.2	38.09	664	13.5
4.25	8.10	12.14	22.67	**6 800**	123.5	102.9	37.65	657	13.7
4.31	8.21	12.32	**23.**	**6 900**	121.7	101.5	37.10	647	13.9
4.33	8.25	12.38	23.10	**6 930**	121.2	101	36.94	644	14
4.38	8.33	12.50	23.33	**7 000**	120	100	36.57	638	14.1
4.46	8.50	12.75	23.47	**7 140**	117.6	98	35.85	625	14.4
4.50	8.57	12.86	**24.**	**7 200**	116.7	97.2	35.56	620	14.5
4.55	8.67	**13.**	24.27	**7 280**	115.4	96.2	35.17	613	14.7
4.59	8.75	13.13	24.50	**7 350**	114.3	95.2	34.83	607	14.8
4.69	8.93	13.39	**25.**	**7 500**	112	93.3	34.13	595	15.1
4.73	**9.**	13.50	25.20	**7 560**	111.1	92.6	33.86	591	15.2
4.75	9.05	13.57	25.33	**7 600**	110.5	92.1	33.68	587	15.3
4.88	9.29	13.93	**26.**	**7 800**	107.7	89.8	32.82	572	15.7
4.90	9.33	**14.**	26.13	**7 840**	107.1	89.3	32.65	569	15.8
4.99	9.50	14.25	26.60	**7 980**	105.3	87.7	32.08	560	16.1
5.	9.52	14.29	26.67	**8 000**	105	87.5	32	558	16.1
5.06	9.64	14.46	**27.**	**8 100**	103.7	86.4	31.60	551	16.3
5.08	9.67	14.50	27.07	**8 120**	103.4	86.2	31.53	550	16.4
5.25	**10.**	**15.**	**28.**	**8 400**	100	83.3	30.48	532	16.9
5.43	10.33	15.50	28.93	**8 680**	96.8	80.7	29.49	514	17.5
5.44	10.36	15.54	**29.**	**8 700**	96.6	80.5	29.43	513	17.5
5.50	10.48	15.71	29.33	**8 800**	95.5	79.6	29.09	507	17.7
5.51	10.50	15.75	29.40	**8 820**	95.2	79.4	29.02	506	17.8
5.60	10.67	**16.**	29.87	**8 960**	93.8	78.1	28.57	498	18.1
5.63	10.71	16.07	**30.**	**9 000**	93.3	77.8	28.44	496	18.1
5.75	10.95	16.43	30.67	**9 200**	91.3	76.1	27.83	485	18.5
5.78	**11.**	16.50	30.80	**9 240**	90.9	75.8	27.70	483	18.6
5.81	11.07	16.60	**31.**	**9 300**	90.3	75.3	27.53	480	18.7
5.96	11.33	**17.**	31.73	**9 520**	88.2	73.5	26.89	469	19.2
6.	11.43	17.14	**32.**	**9 600**	87.5	72.9	26.67	465	19.3
6.04	11.50	17.25	32.20	**9 660**	87	72.5	26.50	462	19.5
6.19	11.79	17.68	**33.**	**9 900**	84.8	70.7	25.85	451	20
6.25	11.90	17.86	33.33	**10 000**	84	70	25.60	446	20.1
6.30	**12.**	**18.**	33.60	**10 080**	83.3	69.4	25.40	443	20.3
6.38	12.14	18.21	**34.**	**10 200**	82.4	68.6	25.10	438	20.6
6.50	12.38	18.57	34.67	**10 400**	80.8	67.3	24.62	429	21
6.56	12.50	18.75	**35.**	**10 500**	80	66.7	24.38	425	21.2
6.65	12.67	**19.**	35.47	**10 640**	78.9	65.8	24.06	420	21.4
6.75	12.86	19.29	**36.**	**10 800**	77.8	64.8	23.70	413	21.8
6.83	**13.**	19.50	36.40	**10 920**	76.9	64.1	23.44	409	22
6.94	13.21	19.82	**37.**	**11 100**	75.7	63.1	23.06	402	22.4
7.	13.33	**20.**	37.33	**11 200**	75	62.5	22.86	399	22.6
7.09	13.50	20.25	37.80	**11 340**	74.1	61.7	22.57	394	22.9
7.13	13.57	20.35	**38.**	**11 400**	73.7	61.4	22.46	392	23
7.25	13.81	20.21	38 67	**11 600**	72.4	60.3	22.07	385	23.4
7.31	13.93	20.89	**39.**	**11 700**	71.8	59.8	21.88	382	23.6
7.35	**14.**	**21.**	39.20	**11 760**	71.4	59.5	21.77	380	23.7
7.50	14.29	21.43	**40.**	**12 000**	70	58.3	21.33	372	24.2
7.69	14.64	21.96	**41.**	**12 300**	68.3	56.9	20.81	363	24.8
7.70	14.67	**22.**	41.07	**12 320**	68.2	56.8	20.78	362	24.8
7.75	14.76	22.15	41.33	**12 400**	67.7	56.5	20.65	360	25
7.88	**15.**	22.50	**42.**	**12 600**	66.7	55.6	20.32	354	25.4
8.	15.24	22.86	42.67	**12 800**	65.6	54.7	20	349	25.8
8.05	15.33	**23.**	42.93	**12 880**	65.2	54.4	19.88	347	26
8.06	15.36	23.04	**43.**	**12 900**	65.1	54.3	19.85	346	26
8.25	15.71	23.57	**44.**	**13 200**	63.6	53	19.39	338	26.6
8.40	**16.**	**24.**	44.80	**13 440**	62.5	52.1	19.05	332	27.1

YARN NUMBER CONVERSION TABLE (*Continued*)

Runs, 1600 yd. per lb.	Cotton, 840 yd. per lb.	Worsted, 560 yd. per lb.	Linen, 300 yd. per lb.	Yards per lb.	Grains per 120 yd.	Grains per 100 yd.	Drams per 1000 yd.	Denier 0.05 g. per 450 meters	Metric, 496 yd. per lb.
8.44	16.07	24.11	**45.**	**13 500**	62.2	51.9	18.96	331	27.2
8.50	16.19	24.29	45.33	**13 600**	61.8	51.5	18.82	328	27.4
8.63	16.43	24.64	**46.**	**13 800**	60.9	50.7	18.55	324	27.8
8.75	16.67	**25.**	46.67	**14 000**	60	50	18.29	319	28.2
8.81	16.79	25.18	**47.**	**14 100**	59.6	49.6	18.16	317	28.4
8.93	**17.**	25.50	47.60	**14 280**	58.8	49	17.93	313	28.8
9.	17.14	25.71	**48.**	**14 400**	58.3	48.6	17.77	310	29
9.10	17.33	**26.**	48.53	**14 560**	57.7	48.1	17.58	307	29.3
9.19	17.50	26.25	**49.**	**14 700**	57.1	47.6	17.41	304	29.6
9.25	17.62	26.43	49.33	**14 800**	56.8	47.3	17.30	302	29.8
9.38	17.86	26.79	**50.**	**15 000**	56	46.7	17.07	298	30.2
9.45	**18.**	**27.**	50.40	**15 120**	55.6	46.3	16.93	295	30.5
9.50	18.10	27.14	50.67	**15 200**	55.3	46.1	16.84	294	30.6
9.56	18.21	27.32	**51.**	**15 300**	54.9	45.8	16.73	292	30.8
9.75	18.57	27.86	**52.**	**15 600**	53.8	44.9	16.41	286	31.4
9.80	18.67	**28.**	52.27	**15 680**	53.6	44.6	16.33	285	31.6
9.94	18.81	28.21	**53.**	**15 900**	52.8	44	16.10	281	32.1
9.98	**19.**	28.50	53.20	**15 960**	52.6	43.9	16.04	280	32.2
10.	19.05	28.57	53.33	**16 000**	52.5	43.8	16	279	32.2
10.13	19.29	28.93	**54.**	**16 200**	51.9	43.2	15.80	276	32.7
10.15	19.33	**29.**	54.13	**16 240**	51.7	43.1	15.76	275	32.7
10.31	19.64	29.46	**55.**	**16 500**	50.9	42.4	15.52	271	33.3
10.50	**20.**	**30.**	**56.**	**16 800**	50	41.6	15.24	266	33.9
10.69	20.36	30.54	**57.**	**17 100**	49.1	40.9	14.97	261	34.5
10.85	20.67	**31.**	57.87	**17 360**	48.4	40.3	14.75	257	35
10.88	20.71	31.07	**58.**	**17 400**	48.2	40.2	14.71	257	35.1
11.	20.95	31.43	58.67	**17 600**	47.7	39.8	14.55	254	35.5
11.03	**21.**	31.50	58.80	**17 640**	47.6	39.7	14.51	253	35.6
11.06	21.07	31.61	**59.**	**17 700**	47.5	39.5	14.46	252	35.7
11.20	21.33	**32.**	59.40	**17 920**	46.9	39	14.29	249	36.1
11.25	21.43	32.14	**60.**	**18 000**	46.7	38.9	14.22	248	36.3
11.44	21.79	32.68	**61.**	**18 300**	45.4	38.3	13.99	244	36.9
11.50	21.90	32.86	61.33	**18 400**	45.7	38	13.91	243	37.1
11.55	**22.**	**33.**	61.60	**18 480**	45.5	37.9	13.85	242	37.3
11.63	22.14	33.21	**62.**	**18 600**	45.2	37.6	13.76	240	37.5
11.81	22.50	33.75	**63.**	**18 900**	44.4	37	13.54	236	38.1
11.90	22.67	**34.**	63.47	**19 040**	44.1	36.8	13.45	235	38.4
12.	22.86	34.29	**64.**	**19 200**	43.8	36.5	13.33	233	38.7
12.07	**23.**	34.50	64.40	**19 320**	43.5	36.2	13.25	231	38.9
12.19	23.21	34.82	**65.**	**19 500**	43.1	35.9	13.13	229	39.3
12.25	23.33	**35.**	65.33	**19 600**	42.9	35.7	13.06	228	39.5
12.38	23.57	35.36	**66.**	**19 800**	42.4	35.4	12.93	226	39.9
12.50	23.81	35.71	66.67	**20 000**	42	35	12.80	223	40.2
12.56	23.93	35.89	**67.**	**20 100**	41.8	34.8	12.74	222	40.5
12.60	**24.**	**36.**	67.20	**20 160**	41.7	34.7	12.70	221	40.6
12.75	24.29	36.43	**68.**	**20 400**	41.2	34.3	12.55	219	41.1
12.94	24.64	36.96	**69.**	**20 700**	40.6	33.8	12.37	216	41.7
12.95	24.67	**37.**	69.07	**20 720**	40.6	33.8	12.36	216	41.8
13.	24.76	37.14	69.33	**20 800**	40.4	33.7	12.31	215	41.9
13.13	**25.**	37.50	**70.**	**21 000**	40	33.3	12.19	213	42.3
13.30	25.33	**38.**	70.93	**21 280**	39.5	32.9	12.03	210	42.9
13.31	25.36	38.04	**71.**	**21 300**	39.4	32.9	12.02	210	42.9
13.50	25.71	38.57	**72.**	**21 600**	38.9	32.4	11.85	207	43.5
13.65	**26.**	**39.**	72.80	**21 840**	38.5	32	11.72	204	44
13.69	26.07	39.11	**73.**	**21 900**	38.4	32	11.69	204	44.2
13.88	26.43	39.64	**74.**	**22 200**	37.8	31.5	11.53	201	44.8
14.	26.67	**40.**	74.67	**22 400**	37.5	31.2	11.43	199	45.2
14.06	26.79	40.18	**75.**	**22 500**	37.3	31.1	11.38	198	45.4
14.18	**27.**	40.50	75.60	**22 680**	37	30.9	11.29	197	45.7
14.25	27.14	40.72	**76.**	**22 800**	36.8	30.7	11.23	196	46
14.35	27.33	**41.**	76.53	**22 960**	36.6	30.5	11.15	194	46.3
14.44	27.50	41.25	**77.**	**23 100**	36.4	30.3	11.08	193	46.6
14.63	27.86	41.79	**78.**	**23 400**	35.9	29.9	10.94	191	47.2
14.70	**28.**	**42.**	78.40	**23 520**	35.7	29.8	10.88	190	47.4
14.81	28.21	42.32	**79.**	**23 700**	35.4	29.5	10.80	188	47.8
15.	28.57	42.86	**80.**	**24 000**	35	29.2	10.67	186	48.4
15.05	28.67	**43.**	80.27	**24 080**	34.9	29.1	10.63	185	48.5
15.19	28.78	43.18	**81.**	**24 300**	34.6	28.8	10.53	184	49
15.23	**29.**	43.50	81.20	**24 360**	34.5	28.7	10.51	183	49.1
15.38	29.29	43.93	**82.**	**24 600**	34.1	28.5	10.41	182	49.6

YARN NUMBER CONVERSION TABLE (*Continued*)

Runs, 1600 yd. per lb.	Cotton, 840 yd. per lb.	Worsted, 560 yd. per lb.	Linen, 300 yd. per lb.	Yards per lb.	Grains per 120 yd.	Grains per 100 yd.	Drams per 1000 yd.	Denier 0.05 g. per 450 meters	Metric, 496 yd. per lb.
15.40	29.33	**44.**	82.13	**24 640**	34.1	28.4	10.39	181	49.7
15.75	**30.**	**45.**	**84.**	**25 200**	33.3	27.8	10.16	177	50.8
16.	30.48	45.71	85.33	**25 600**	32.8	27.3	10	174	51.6
16.10	30.67	**46.**	85.87	**25 760**	32.6	27.2	9.94	173	51.9
16.13	30.71	46.07	**86.**	**25 800**	32.6	27.1	9.92	173	52
16.27	**31.**	46.50	86.80	**26 040**	32.3	26.9	9.83	171	52.5
16.50	31.43	47.14	**88.**	**26 400**	31.8	26.5	9.70	169	53.2
16.80	**32.**	**48.**	89.60	**26 880**	31.3	26	9.52	166	54.2
16.88	32.14	48.21	**90.**	**27 000**	31.1	25.9	9.48	165	54.4
17.	32.38	48.57	90.67	**27 200**	30.9	25.7	9.41	164	54.8
17.25	32.86	49.29	**92.**	**27 600**	30.4	25.4	9.28	162	55.6
17.32	**33.**	49.50	92.40	**27 720**	30.3	25.3	9.24	161	55.9
17.50	33.33	**50.**	93.33	**28 000**	30	25	9.14	159	56.5
17.63	33.57	50.36	**94.**	**28 200**	29.8	24.8	9.08	158	56.8
17.85	**34.**	**51.**	95.20	**28 560**	29.4	24.5	8.96	156	57.6
18.	34.29	51.43	**96.**	**28 800**	29.2	24.3	8.89	155	58.1
18.20	34.67	**52.**	97.07	**29 120**	28.8	24	8.79	153	58.7
18.38	**35.**	52.50	**98.**	**29 400**	28.6	23.8	8.71	152	59.3
18.75	35.71	53.57	**100.**	**30 000**	28	23.3	8.53	149	60.5
18.90	**36.**	**54.**	100.80	**30 240**	27.8	23.1	8.47	148	61
19.	36.19	54.29	101.33	**30 400**	27.6	23	8.42	147	61.3
19.42	**37.**	55.50	103.60	**31 080**	27	22.5	8.24	144	62.6
19.50	37.14	55.72	**104.**	**31 200**	26.9	22.4	8.21	143	62.9
19.60	37.33	**56.**	104.53	**31 360**	26.8	22.3	8.16	142	63.2
19.95	**38.**	**57.**	106.40	**31 920**	26.3	21.9	8.02	140	64.3
20.	38.10	57.14	106.67	**32 000**	26.3	21.9	8	140	64.4
20.25	38.57	57.86	**108.**	**32 400**	25.9	21.6	7.90	138	65.3
20.30	38.67	**58.**	108.27	**32 480**	25.9	21.6	7.88	138	65.5
20.47	**39.**	58.50	109.20	**32 760**	25.6	21.4	7.81	136	66
21.	**40.**	**60.**	**112.**	**33 600**	25	20.8	7.62	133	67.7
21.52	**41.**	61.50	114.80	**34 440**	24.4	20.3	7.43	130	69.4
21.70	41.33	**62.**	115.73	**34 720**	24.2	20.2	7.37	129	70
21.75	41.43	62.14	**116.**	**34 800**	24.1	20.1	7.36	128	70.2
22.	41.90	62.86	117.33	**35 200**	23.9	19.9	7.27	127	71
22.05	**42.**	**63.**	117.60	**35 280**	23.8	19.8	7.26	127	71.1
22.40	42.67	**64.**	119.47	**35 840**	23.4	19.5	7.14	125	72.3
22.50	42.86	64.29	**120.**	**36 000**	23.3	19.4	7.11	124	72.6
22.57	**43.**	64.50	120.40	**36 120**	23.3	19.4	7.09	124	72.8
23.	43.81	65.71	122.67	**36 800**	22.8	19	6.96	121	74.2
23.10	**44.**	**66.**	123.20	**36 960**	22.7	18.9	6.93	121	74.5
23.25	44.29	66.43	**124.**	**37 200**	22.6	18.8	6.88	120	75
23.62	**45.**	67.50	**126.**	**37 800**	22.2	18.5	6.77	118	76.2
23.80	45.33	**68.**	126.93	**38 080**	22.1	18.4	6.72	117	76.8
24.	45.71	68.57	**128.**	**38 400**	21.9	18.2	6.67	116	77.4
24.15	**46.**	**69.**	128.80	**38 640**	21.7	18.1	6.63	115	77.9
24.50	46.67	**70.**	130.67	**39 200**	21.4	17.9	6.53	114	79
24.67	**47.**	70.50	131.60	**39 480**	21.3	17.7	6.48	113	79.6
24.75	47.14	70.72	**132.**	**39 600**	21.2	17.7	6.46	113	79.8
25.	47.62	71.43	133.33	**40 000**	21	17.5	6.40	112	80.6
25.20	**48.**	**72.**	134.40	**40 320**	20.8	17.4	6.35	111	81.3
25.50	48.57	72.86	**136.**	**40 800**	20.6	17.2	6.27	109	82.2
25.72	**49.**	73.50	137.20	**41 160**	20.4	17	6.22	108	83
25.90	49.33	**74.**	138.13	**41 440**	20.3	16.9	6.18	108	83.5
26.	49.52	74.29	138.67	**41 600**	20.2	16.8	6.15	107	83.9
26.25	**50.**	75.	**140.**	**42 000**	20	16.7	6.10	106	84.7
26.60	50.67	**76.**	141.87	**42 560**	19.7	16.4	6.01	105	85.8
26.77	**51.**	76.50	142.80	**42 840**	19.6	16.3	5.98	104	86.4
27.	51.43	77.14	**144.**	**43 200**	19.4	16.2	5.93	103	87.1
27.30	**52.**	**78.**	145.60	**43 680**	19.2	16	5.86	102	88.1
27.75	52.86	79.29	**148.**	**44 400**	18.9	15.8	5.76	101	89.5
27.82	**53.**	79.50	148.40	**44 520**	18.9	15.7	5.75	100	89.7
28.	53.33	**80.**	149.33	**44 800**	18.7	15.6	5.71	100	90.3
28.35	**54.**	**81.**	151.20	**45 360**	18.5	15.4	5.64	98	91.4
28.50	54.29	81.43	**152.**	**45 600**	18.4	15.4	5.61	98	91.9
28.70	54.67	**82.**	153.07	**45 920**	18.3	15.2	5.57	97	92.6
28.87	**55.**	82.50	**154.**	**46 200**	18.2	15.2	5.54	97	93.1
29.	55.24	82.86	154.67	**46 400**	18.1	15.1	5.51	96	93.5
29.25	55.71	83.57	**156.**	**46 800**	17.9	15	5.47	95	94.3
29.40	**56.**	**84.**	156.80	**47 040**	17.8	14.9	5.44	95	94.8
29.92	**57.**	85.50	159.60	**47 880**	17.5	14.6	5.34	93	96.5

YARN NUMBER CONVERSION TABLE (*Continued*)

Runs, 1600 yd. per lb.	Cotton, 840 yd. per lb.	Worsted, 560 yd. per lb.	Linen, 300 yd. per lb.	Yards per lb.	Grains per 120 yd.	Grains per 100 yd.	Drams per 1000 yd.	Denier 0.05 g. per 450 meters	Metric, 496 yd. per lb.
30.	57.14	85.71	**160.**	**48 000**	17.5	14.6	5.33	93	96.8
30.20	57.33	**86.**	160.53	**48 160**	17.4	14.5	5.31	93	97.1
30.45	**58.**	**87.**	162.40	**48 720**	17.2	14.4	5.25	92	98.2
30.75	58.57	87.86	**164.**	**49 200**	17.1	14.2	5.20	91	99.2
30.80	58.67	**88.**	164.27	**49 280**	17	14.2	5.19	91	99.3
30.97	**59.**	88.50	165.20	**49 560**	17	14.1	5.16	90	99.9
31.	59.05	88.57	165.33	**49 600**	16.9	14.1	5.16	90	100
31.50	**60.**	**90.**	**168.**	**50 400**	16.7	13.9	5.07	89	101.6
32.	60.95	91.43	170.67	**51 200**	16.4	13.7	5	87	103.2
32.02	**61.**	91.50	170.80	**51 240**	16.4	13.7	4.99	87	103.3
32.20	61.33	**92.**	171.73	**51 520**	16.3	13.6	4.96	87	103.9
32.25	61.43	92.14	**172.**	**51 600**	16.3	13.6	4.96	87	104
32.55	**62.**	**93.**	173.60	**52 080**	16.1	13.4	4.91	86	105
32.90	62.67	**94.**	175.47	**52 640**	16	13.3	4.86	85	106.1
33.	62.86	94.28	**176.**	**52 800**	15.9	13.3	4.84	85	106.4
33.07	**63.**	94.50	176.40	**52 920**	15.9	13.2	4.83	84	106.7
33.60	**64.**	**96.**	179.20	**53 760**	15.6	13	4.76	83	108.4
33.75	64.28	96.42	**180.**	**54 000**	15.6	13	4.74	83	108.9
34.	64.76	97.18	181.33	**54 400**	15.4	12.9	4.70	82	109.7
34.12	**65.**	97.50	**182.**	**54 600**	15.4	12.8	4.68	82	110.1
34.30	65.33	**98.**	182.93	**54 880**	15.3	12.8	4.66	81	110.6
34.50	65.71	98.57	**184.**	**55 200**	15.2	12.7	4.63	81	111.3
34.65	**66.**	**99.**	184.80	**55 440**	15.2	12.6	4.61	80	111.8
35.	66.67	**100.**	186.67	**56 000**	15	12.5	4.57	80	112.9
35.17	**67.**	100.50	187.60	**56 280**	14.9	12.4	4.54	79	113.5
35.25	67.14	100.71	**188.**	**56 400**	14.9	12.4	4.53	79	113.7
35.70	**68.**	**102.**	190.40	**57 120**	14.7	12.3	4.48	78	115.1
36.	68.57	102.86	**192.**	**57 600**	14.6	12.2	4.44	78	116.1
36.22	**69.**	103.50	193.20	**57 960**	14.5	12.1	4.41	77	116.8
36.40	69.33	**104.**	194.13	**58 240**	14.4	12	4.39	77	117.4
36.75	**70.**	**105.**	**196.**	**58 800**	14.3	11.9	4.35	76	118.5
37.	70.47	105.71	197.33	**59 200**	14.2	11.8	4.32	75	119.3
37.10	70.67	**106.**	197.87	**59 360**	14.1	11.8	4.31	75	121.9
37.27	**71.**	106.50	198.80	**59 640**	14.1	11.7	4.29	75	120.2
37.50	71.42	107.12	**200.**	**60 000**	14	11.7	4.26	74	121
37.80	**72.**	**108.**	201.60	**60 480**	13.9	11.6	4.23	74	121.9
38.	72.38	108.57	202.67	**60 800**	13.8	11.5	4.21	73	122.6
38.25	72.86	109.28	**204.**	**61 200**	13.7	11.4	4.18	73	123.4
38.82	**73.**	109.50	204.40	**61 320**	13.7	11.4	4.17	73	123.6
38.50	73.33	**110.**	205.33	**61 600**	13.6	11.4	4.15	72	124.2
38.85	**74.**	**111.**	207.20	**62 160**	13.5	11.3	4.11	72	125.3
39.	74.28	111.43	**208.**	**62 400**	13.4	11.2	4.10	72	125.8
39.20	74.67	**112.**	209.07	**62 720**	13.4	11.2	4.08	71	126.4
39.37	**75.**	112.50	**210.**	**63 000**	13.3	11.1	4.06	71	127
39.75	75.71	113.57	**212.**	**63 600**	13.2	11	4.02	70	128.2
39.90	**76.**	**114.**	212.80	**63 840**	13.2	11	4.01	70	128.7
40.	76.19	114.29	213.33	**64 000**	13.1	10.9	4	70	129
40.42	**77.**	115.50	215.60	**64 680**	13	10.8	3.95	69	130.4
40.50	77.14	115.71	**216.**	**64 800**	13	10.8	3.95	69	130.6
40.60	77.33	**116.**	216.53	**64 969**	12.9	10.8	3.94	69	131
40.95	**78.**	**117.**	218.40	**65 520**	12.8	10.7	3.90	68	132.1
41.	78.09	117.14	218.67	**65 600**	12.8	10.7	3.90	68	132.2
41.25	78.58	117.86	**220.**	**66 000**	12.7	10.6	3.87	68	133.1
41.30	78.67	**118.**	220.27	**66 080**	12.7	10.6	3.87	67	133.2
42.	**80.**	**120.**	**224.**	**67 200**	12.5	10.4	3.80	66	135.5

REPORT OF COMMITTEE D-14
ON
SCREEN WIRE CLOTH

The principal activity of Committee D-14 on Screen Wire Cloth since submission of its last annual report in 1930 has been the exposure test program of Subcommittee IV on Testing of Screen Wire Cloth under the chairmanship of G. Willard Quick. A paper giving the results of the exposure tests to date has been prepared by Mr. Quick. This paper which is appended hereto reports the conclusion of this test program.

The resignation of R. W. Woodward as chairman of Committee D-14 was accepted at the meeting held during the annual meeting of the Society at Atlantic City, N. J., in June, 1934. A chairman was elected at this meeting but was unfortunately unable to accept due to pressure of other work. Because of the rather special character of the work of the committee, it is proving to be rather difficult to secure someone for this important office.

The secretary of the committee, Mr. W. H. Bassett, died on July 21, 1934. In the absence of a chairman and a secretary, Mr. John R. Freeman, Jr., was appointed by the Executive Committee of the Society as Secretary *pro tem* pending election of a chairman and a secretary.

This report has been submitted to letter ballot of the committee, which consists of 14 members; 10 members returned their ballots, of whom 9 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

John R. Freeman, Jr.,
Secretary pro tem.

APPENDIX

ATMOSPHERIC EXPOSURE TESTS ON NON-FERROUS SCREEN WIRE CLOTH[1]

BY G. W. QUICK[2]

INTRODUCTION

In June, 1924, a program of atmospheric exposure tests on seven compositions of non-ferrous screen wire cloth was formulated by Committee D-14, the materials being furnished by members of the committee. Chemical analyses and certain laboratory tests were conducted at the direction of Subcommittee IV on Testing of Screen Wire Cloth, under the chairmanship of the author of this report, who represented the National Bureau of Standards on the committee. The exposure racks were placed on Government property as follows: (1) U. S. Bureau of Mines, Pittsburgh, Pa., (2) Lighthouse Depot, Portsmouth, Va., (3) Cristobal, Canal Zone, and (4) The National Bureau of Standards, Washington, D. C. The National Bureau of Standards arranged for the inspection and periodical reports of the condition of the exposed specimens. Previous reports of the committee have given details of the tests and information on the condition of the test specimens.[3]

This report is a summary of the essential details and results of the exposure tests at the four locations over a period of approximately 9 yr.

During the summer of 1934 the necessity arose of removing the specimens at Portsmouth, Va., because the building on which they were located was to be razed. No other location was available in the immediate vicinity and since failure had already occurred in most of the materials at Pittsburgh and several failures had been reported at Cristobal, although none had occurred at Washington, it was believed that more useful information would be obtained from an examination, at this time, of the remaining specimens than to prolong the tests until all materials had failed. Therefore, it was decided to terminate the tests at the first three locations. As no failures had occurred at Washington and extra materials which had been exposed for approximately the same length of time were available for examination it was decided to continue the exposure of the framed materials at that location.

MATERIALS AND PREPARATION OF SPECIMENS

Seven non-ferrous materials in the form of 16-mesh insect-screen cloth woven from wire 0.0113 in. in diameter were used. Their nominal compositions and the compositions determined by analysis of samples of the finished cloth are given in Table I.

Of the seven compositions, unalloyed copper and the 90 copper - 10 zinc alloy, which correspond to Class A and Class B material, respectively, of the Society's Standard Specifications for Non-Ferrous Insect Screen Cloth (B 50 - 29),[4] were commercially available at the time the program was started and have continued to be since. The other alloys were not on the market at the time but were included in the tests on the recommendation of various members of the committee.

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[1] Published by permission of the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Associate Metallurgist, National Bureau of Standards, Washington, D. C.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 384 (1925); Vol. 26, Part I, p. 492 (1926); Vol. 27, Part I, p. 562 (1927); Vol. 30, Part I, p. 864 (1930).

[4] 1933 Book of A.S.T.M. Standards, Part I, p. 725.

Each material was mounted in three types of frames: (1) 30 by 36-in. copper frames; (2) 30 by 36-in. wood frames; and (3) 12 by 12-in. (inside dimensions) wood frames. The cloth was mounted in the two larger frames by the Cincinnati Fly Screen Co. in the presence of the author. The cloth in the small frames was mounted with very little tension in the screen at the National Bureau of Standards. The three types of frames were shown in the committee's report for 1925.[1] The frames were numbered for identification to correspond to the alloy numbers (Table I): the 30 by 36-in. wood frames were numbered 1 to 7; the 30 by 36-in. copper frames were numbered 11 to 17; and the 12 by 12-in. wood frames, 21 to 27. The wood frames were painted several times during the exposure period with basic carbonate white lead paint. The copper frames were not painted.

TABLE I.—COMPOSITION OF MATERIALS USED IN EXPOSURE TESTS OF SCREEN WIRE CLOTH.

n.d. = not detected.

Designation of Alloy	Nominal Composition, per cent	Composition Determined by Analysis, per cent[a]								
		Copper	Zinc	Nickel	Tin	Iron	Lead	Manganese	Silicon	Aluminum
No. 1	90 copper, 10 zinc	90.7	9.05[b]	n.d.	0.23	less than 0.02	n.d.	....	....	....
No. 2	80 copper, 20 zinc	80.1	19.88	n.d.	....	less than 0.02	n.d.	....	....	....
No. 3	75 copper, 20 nickel, 5 zinc	73.9	5.4	19.8	....	0.3	....	0.5	0.06	....
No. 4	70 nickel, 30 copper (approx.)	26.5	....	68.3	....	2.4	....	2.7	....	....
No. 5	Unalloyed copper	99.94	n.d.	n.d.	less than 0.01	....	n.d.	....	....	....
No. 6	98 copper, 2 tin	98.3	n.d.	n.d.	1.8	less than 0.01	n.d.	....	n.d.	....
No. 7	95 copper, 5 aluminum	95.2	n.d.	n.d.	0.08	....	n.d.	....	....	4.8

[a] Made by the Chemistry Division of the National Bureau of Standards.
[b] By difference.

The four test locations were selected to represent different atmospheric conditions, as follows: (1) The Bureau of Mines at Pittsburgh, a "heavy" industrial atmosphere; (2) The Lighthouse Depot at Portsmouth, Va., a temperate seacoast atmosphere with some industrial contamination; (3) Cristobal, a tropical seacoast with some industrial contamination; and (4) The National Bureau of Standards, Washington, a normal inland atmosphere.

Specimens of each material (unframed) were exposed in Washington, adjacent to the corresponding framed specimen, approximately 1 yr. after the start of the exposure tests. Tension tests were made on specimens clipped from this material from time to time to demonstrate the changes in tensile strength on exposure. Results of these tests over a period of about 3½ yr. were given in the appendix to the 1930 report of Committee D-14. Through the cooperation of several Government laboratories, daily determinations of the sulfur dioxide content of the atmosphere over a period of one year were made at or near each of the four exposure stations. The results were also published in the appendix to the report in 1930 along with the results of inspections of the screen specimens at the four stations up to that date.

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[1] Report of Committee D-14 on Screen Wire Cloth, *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 384 (1925).

TABLE II.—CONDITION OF SCREEN-WIRE MATERIALS AFTER EXPOSURE AT PITTSBURGH, PA., FROM OCTOBER 29, 1925, TO JULY 10, 1934.

Material	Frame	Time Exposed Until First Failure	Appearance at End of Test
No. 1—90 copper, 10 zinc........	30 by 36 in., wood	7 yr., 6 mo.	Uniform dark color. A few wires corroded through near the top. A few wires enlarged from corrosion products.
	30 by 36 in., copper	7 yr., 6 mo.	Uniform dark color; holes at top and edge. Over half of cloth torn out by a slate in storm.
	12 by 12 in., wood	7 yr., 6 mo.	Uniform dark color; a few wires corroded through near the top.
No. 2—80 copper, 20 zinc.........	30 by 36 in., wood	6 yr., 5 mo.	Very brittle; most of the cloth entirely gone. Dark color.
	30 by 36 in., copper	6 yr., 4 mo.	Dark color; heavy corrosion products on some areas; other areas, the wires are thin, many holes; brittle.
	12 by 12 in., wood	6 yr., 10 mo.	Dark color; number of holes; brittle.
No. 3—75 copper, 20 nickel, 5 zinc	30 by 36 in., wood	6 yr., 11 mo.	Dark color; badly corroded, several holes.
	30 by 36 in., copper	7 yr., 3 mo.	Dark color; badly corroded, several holes.
	12 by 12 in., wood	8 yr., 2 mo.	Dark color; badly corroded, two holes near top.
No. 4—70 nickel, 30 copper (approx.).........	30 by 36 in., wood	4 yr., 8 mo.	Dark color; badly corroded, most of the cloth gone.
	30 by 36 in., copper	4 yr., 8 mo.	Dark color; badly corroded, most of the cloth gone.
	12 by 12 in., wood	4 yr.	Dark color; badly corroded, considerable cloth gone near top.
No. 5—Copper, unalloyed......	30 by 36 in., wood	....	Dark color; considerable corrosion; wires thin near top.
	30 by 36 in., copper	7 yr., 6 mo.	Dark color; considerable corrosion; wires thin with number of holes near the top.
	12 by 12 in., wood	....	Considerable corrosion; no holes.
No. 6—98 copper, 2 tin..........	30 by 36 in., wood	7 yr., 9 mo.	Dark color; a number of small holes near the top.
	30 by 36 in., copper	7 yr., 10 mo.	Dark color; a number of small holes near the top.
	12 by 12 in., wood	7 yr., 6 mo.	Dark color; a number of small holes near the top.
No. 7—95 copper, 5 aluminum....	30 by 36 in., wood	5 yr., 7 mo.	Entirely failed; most of the cloth corroded away.
	30 by 36 in., copper	5 yr., 7 mo.	Entirely failed; most of the cloth corroded away.
	12 by 12 in., wood	4 yr., 10 mo.	Entirely failed; most of the cloth corroded away.

RESULTS OF ATMOSPHERIC EXPOSURE TESTS

Failure in the exposed screen cloth was considered to have occurred when there was a break in the wire in at least one place as a result of corrosion. The first failures occurred at Portsmouth in the 80 copper – 20 zinc material (No. 2) in the 30 by 36-in. wood frame from dezincification after 4 yr. exposure. The 70 nickel – 30 copper material in the 12 by 12-in. frame (No. 24) failed at Pittsburgh after 4 yr. exposure. The 30 by 36-in. wood frame (No. 6), which contained the 98 copper – 2 tin material, came apart and had to be removed although the wires were still in excellent condition. These failures were reported together with photographs of the failed specimens in the 1930 report. Since that time at least one failure has occurred in each of the materials exposed at Pittsburgh. At Cristobal, the 80 copper – 20 zinc material (No. 2) failed in both the copper and wood 30 by 36-in. frames. The 12 by 12-in. wood frames at Cristobal were destroyed in some unknown manner after 4 yr. exposure. The occurrence of failures and condition of the materials at the termination of the exposure period at Pittsburgh, Portsmouth, and Cristobal are summarized in Tables II, III and IV. All of the specimens exposed at Washington are in good condition.

TABLE III.—CONDITION OF SCREEN-WIRE MATERIALS AFTER EXPOSURE AT PORTSMOUTH, VA., FROM OCTOBER 28, 1925, TO MAY 1, 1934.

Material	Frame	Time Exposed Until First Failure	Appearance at End of Test
No. 1—90 copper, 10 zinc........	30 by 36 in., wood	....	Dark color; no holes.
	30 by 36 in., copper	....	Dark color; no holes.
	12 by 12 in., wood	....	Dark color; no holes.
No. 2—80 copper, 20 zinc........	30 by 36 in., wood	4 yr.	Entirely failed; most of the cloth gone; very brittle.
	30 by 36 in., copper	4 yr., 2 mo.	Failed from dezincification; dark color.
	12 by 12 in., wood	4 yr., 6 mo.	Failed from dezincification; dark color.
No. 3—75 copper, 20 nickel, 5 zinc	30 by 36 in., wood	....	Material lost in storm.
	30 by 36 in., copper	....	Dark color; no holes.
	12 by 12 in., wood	....	Dark color; no holes.
No. 4—70 nickel, 30 copper (approx.)..........	30 by 36 in., wood	....	Dark color; no holes.
	30 by 36 in., copper	....	Dark color; no holes.
	12 by 12 in., wood	....	Partly lost in storm.
No. 5—Copper, unalloyed......	30 by 36 in., wood	....	Dark color; no holes.
	30 by 36 in., copper	....	Dark color; no holes.
	12 by 12 in., wood	....	Material lost in storm.
No. 6—98 copper, 2 tin..........	30 by 36 in., wood	....	Frame failed after 4 years' exposure. Cloth in good condition.
	30 by 36 in., copper	....	Dark color; no holes.
	12 by 12 in., wood	....	Dark color; no holes.
No. 7—95 copper, 5 aluminum....	30 by 36 in., wood	....	Dark color; no holes.
	30 by 36 in., copper	....	Material lost in storm.
	12 by 12 in., wood	....	Dark color; no holes.

TABLE IV.—CONDITION OF MATERIALS AFTER EXPOSURE AT CRISTOBAL, CANAL ZONE, FROM NOVEMBER 16, 1925, TO JANUARY 19, 1935.

Material	Frame[a]	Time Exposed Until First Failure	Appearance at End of Test
No. 1—90 copper, 10 zinc........	30 by 36 in., wood	....	Uniform dark color. Wires brittle; one bend to break.
	30 by 36 in., copper	....	Uniform dark color. Wires brittle; one bend to break.
No. 2—80 copper, 20 zinc........	30 by 36 in., wood	4 yr., 6 mo.	Considerable green patina on the fragments of cloth.
	30 by 36 in., copper	About 5 yr.	Considerable green patina on the fragments of cloth.
No. 3—75 copper, 20 nickel, 5 zinc	30 by 36 in., wood	....	Dark color with greenish tinge, some wires enlarged with corrosion products. Two or three bends to break.
	30 by 36 in., copper	....	Dark color with greenish tinge, some wires enlarged with corrosion products. Two or three bends to break. Damaged in handling.
No. 4—70 nickel, 30 copper (approx.).........	30 by 36 in., wood	....	Dark color uniformly flecked with yellow. Tough; more than 12 bends to break wires.
	30 by 36 in., copper	....	Dark color uniformly flecked with yellow. Tough; more than 12 bends to break wires.
No. 5—Copper (unalloyed)....	30 by 36 in., wood	....	Uniform dark color with scattered spots of brittle bluish-green vitreous-like material in a few of the openings.
	30 by 36 in., copper	....	Uniform dark color with spots of copper salts deposited sparsely over this area. Some spots of salts segregated in several lines crossing each other at right angles. Very brittle at these points. Many wires would break when salts were picked off.
No. 6—98 copper, 2 tin..........	30 by 36 in., wood	....	Uniform dark color with a few spots of salts scattered over the specimen, particularly along one vertical edge. Wires did not break when the salts were picked off. About two bends to break the wires. Greenish tinge.
	30 by 36 in., copper	....	Uniform dark color with a few spots of salts scattered over the specimen, particularly along one vertical edge. Wires did not break when the salts were picked off. About two bends to break the wires. Greenish tinge. Torn along the bottom edge; probably caused in shipment.
No. 7—95 copper, 5 aluminum....	30 by 36 in., wood	....	Uniform dark color with greenish tinge. Brittle; one bend to break wires.
	30 by 36 in., copper	....	Uniform dark color with greenish tinge. Brittle; one bend to break wires. Torn along bottom edge; may have been caused in shipment.

[a] All of the 12 by 12-in. specimens destroyed or lost after 4 years' exposure.

Figures 1 to 7 show the appearance of the seven materials after exposure at Pittsburgh. The 12 by 12-in. wood frames are used in these illustrations except for material No. 5 which is in the 30 by 36-in. copper frame. This was the only frame in which the unalloyed copper had failed. To show more clearly the way corrosion had affected materials Nos. 2 (80 copper - 20 zinc), 3 (75 copper - 20 nickel - 5 zinc) and 4 (70 nickel - 30 copper, approx.), two small pieces of each are shown in Figs. 8, 9 and 10. In each case one piece was rubbed and bent with the fingers to remove the corrosion products and to show the brittleness and fineness of the wires. The products of corrosion are also shown in the photographs. A microscopic examination of the cross-section of the wires of the several materials exposed at Pittsburgh showed that the corrosion penetrated the wires rather uniformly. The cores of the corroded wires appeared to be sound metal except in material No. 2 (80 copper - 20 zinc) in which the zinc apparently had been removed from the copper, leaving the latter porous and brittle.

At Portsmouth, material No. 2 (80 copper - 20 zinc) failed in each of the three frames after 4 to 4½ yr. exposure. This failure was described in the 1930 Report. The appearance was similar to that of the same material exposed at Pittsburgh (Fig. 8). At Cristobal this material also became brittle from dezincification and failed badly after 4½ to 5 yr. exposure in the 30 by 36-in. wood and copper frames. A photograph of the material from the copper frame is shown in Fig. 11.

Material No. 5 (copper, unalloyed), exposed in the 30 by 36-in. copper frame at Cristobal for approximately 9 yr., showed two well-defined narrow bands of corrosion products extending across the screen at right angles to one another (Fig. 12), and occasional spots of similar corrosion products distributed at random over the entire screen. Figure 13 shows a small area from one of the bands of corrosion products at higher magnification. When the deposits of corrosion products at these spots were picked off, the wires were found to be very thin or corroded through as indicated by arrows 1 and 2 in Fig. 13. Arrow 3 indicates one of the larger deposits, under which the wire was found to be corroded through.

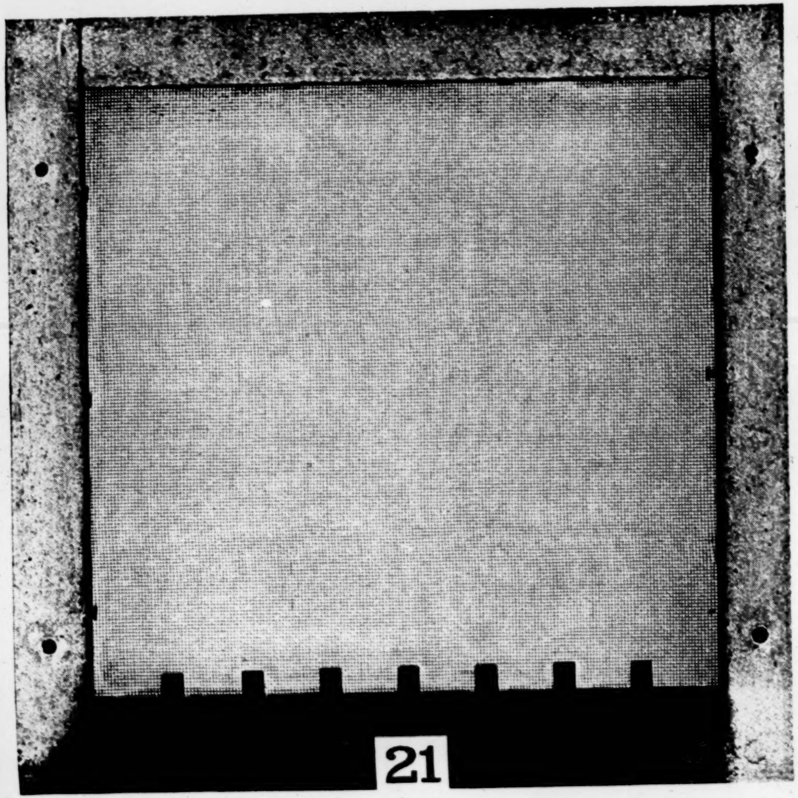
Material No. 6 (98 copper - 2 tin), exposed at Cristobal for approximately 9 yr., also was flecked with spots of corrosion products scattered more numerously over the upper than the lower half of the screen. The wires underneath the corrosion products were not greatly reduced in size and none was corroded through.

A distinct, uniformly greenish patina was formed on all of the materials exposed at Cristobal except material No. 4 (70 nickel - 30 copper, approx.) which was uniformly flecked with yellow. The patina was most pronounced on material No. 2 (80 copper - 20 zinc). No colored patina was noticeable on any of the materials exposed at Pittsburgh, Portsmouth, or Washington.

TENSILE STRENGTH OF THE MATERIALS BEFORE AND AFTER EXPOSURE

Specimens of the screen wire cloth for tension tests were clipped from each of the frames containing sufficient material after the exposure period at Pittsburgh, Portsmouth and Cristobal (and from the extra material exposed for this purpose at Washington). From each of the larger frames, 8 specimens were cut parallel to (longitudinal specimens) and 6 specimens perpendicular to (transverse specimens) the direction of weaving of the cloth. From the 12 by 12-in. frames, 4 specimens were cut in each direction. Only two specimens in each direction were cut at this time from each of the materials exposed at Washington.

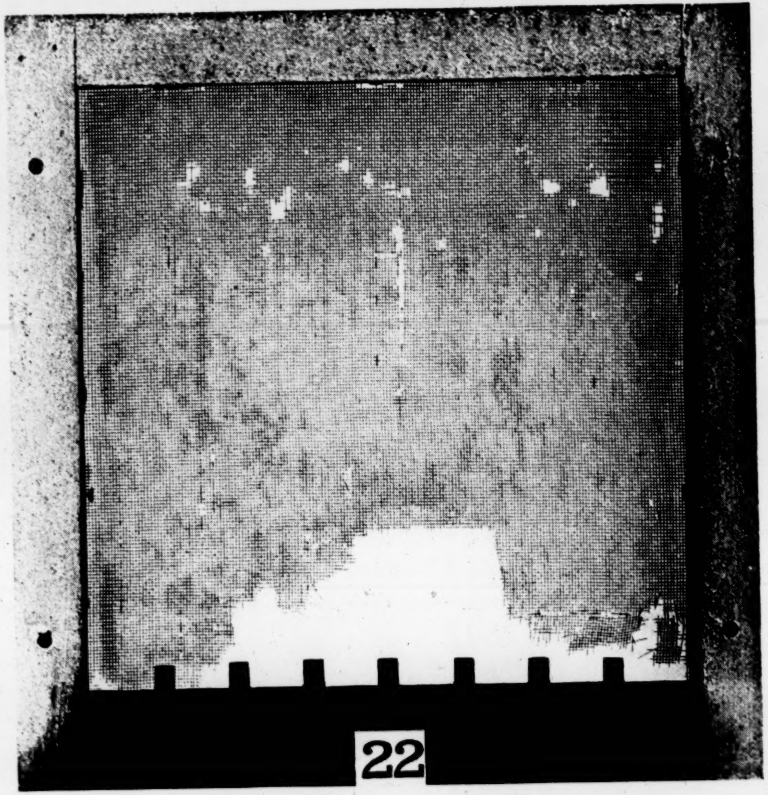
The specimens were 15 strands wide with a central reduced section about 2½ in. long. The reduced section was made by clipping and removing two wires from each side at the mid-length of the specimen. When tested, such specimens almost invariably broke in the mid-length. The materials from some of the frames could not be tested because of loss during storms, failure of frames or other reasons.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

Fig. 1.—Appearance of Material No. 1 (90 Copper–10 Zinc) in the 12 by 12-in. Wood Frame After 9 yr. Continuous Atmospheric Exposure at Pittsburgh.

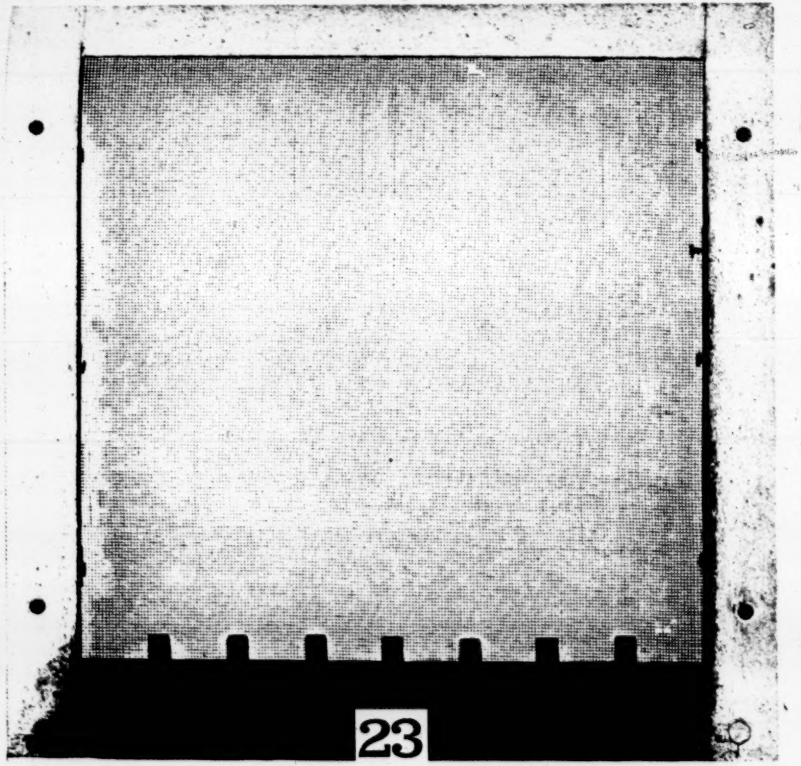
A few of the wires near the top are corroded through.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

Fig. 2.—Appearance of Material No. 2 (80 Copper–20 Zinc) in the 12 by 12-in. Wood Frame After 9 yr. Continuous Exposure at Pittsburgh.

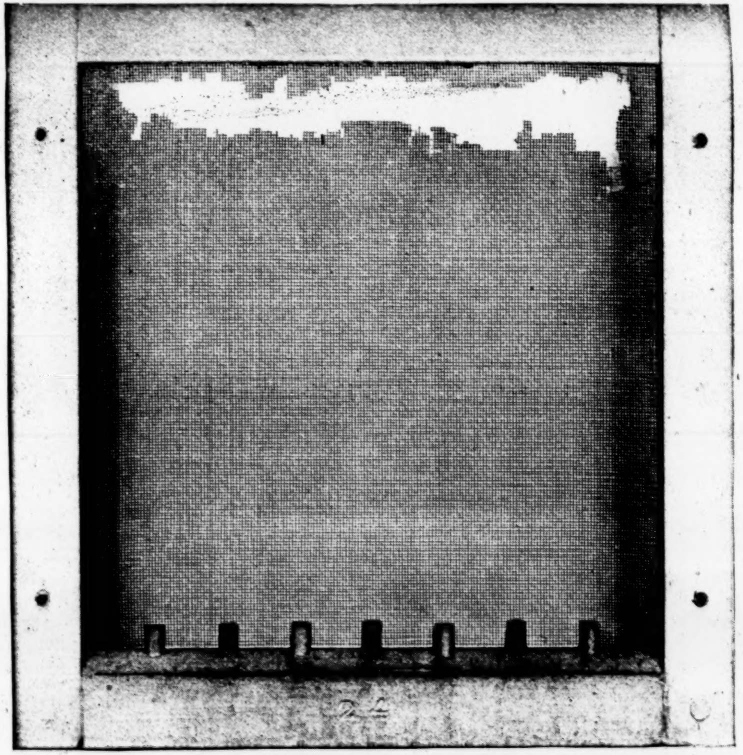
The material is badly corroded, very brittle, and has numerous holes.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

FIG. 3.—Appearance of Material No. 3 (75 Copper–20 Nickel–5 Zinc) in the 12 by 12-in. Wood Frame After 9 yr. Continuous Exposure at Pittsburgh.

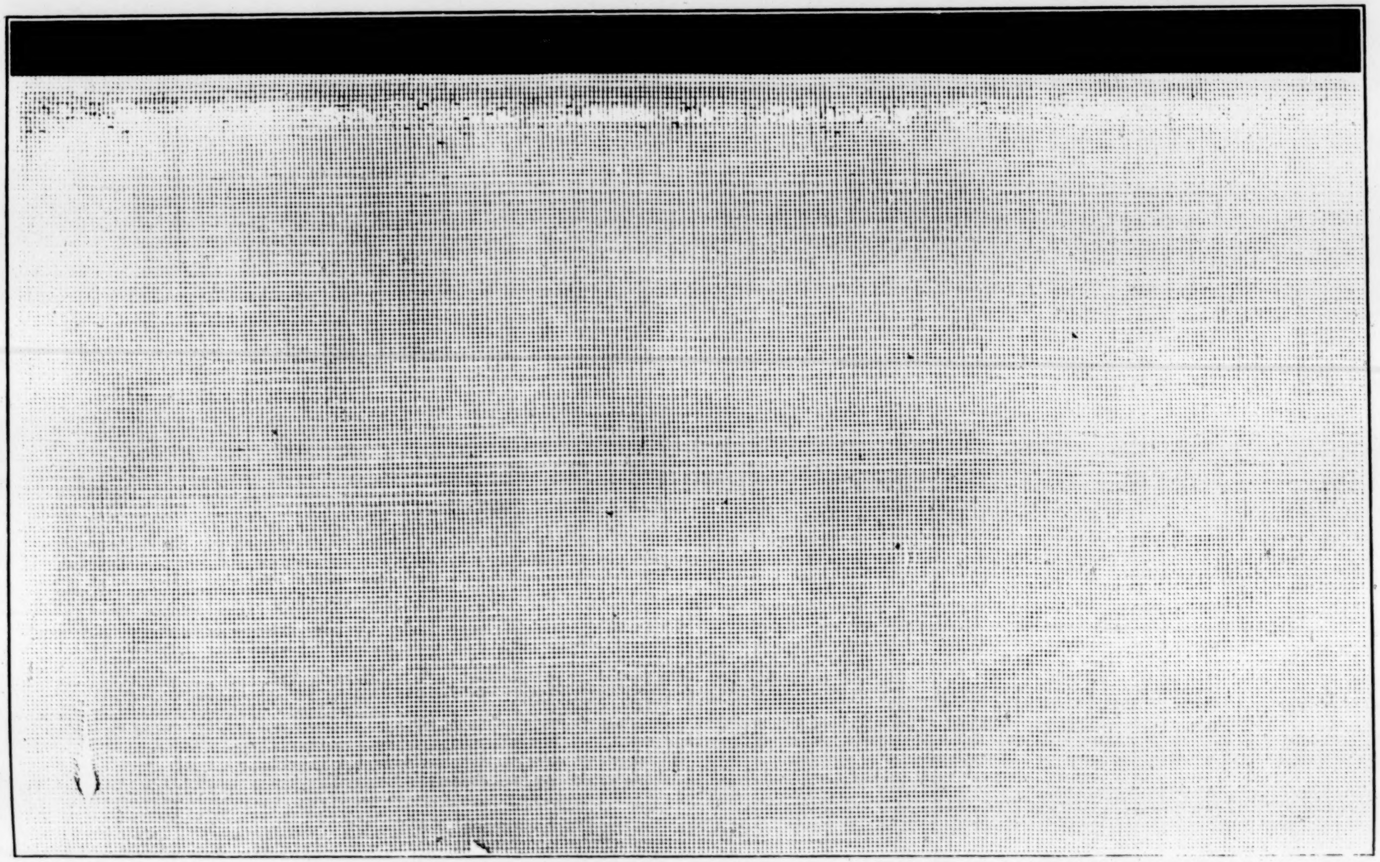
The material is badly corroded and has a few holes near the top and bottom.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

FIG. 4.—Appearance of Material No. 4 (70 Nickel–30 Copper, Approx.) in the 12 by 12-in. Wood Frame After 4 yr. Continuous Exposure at Pittsburgh.

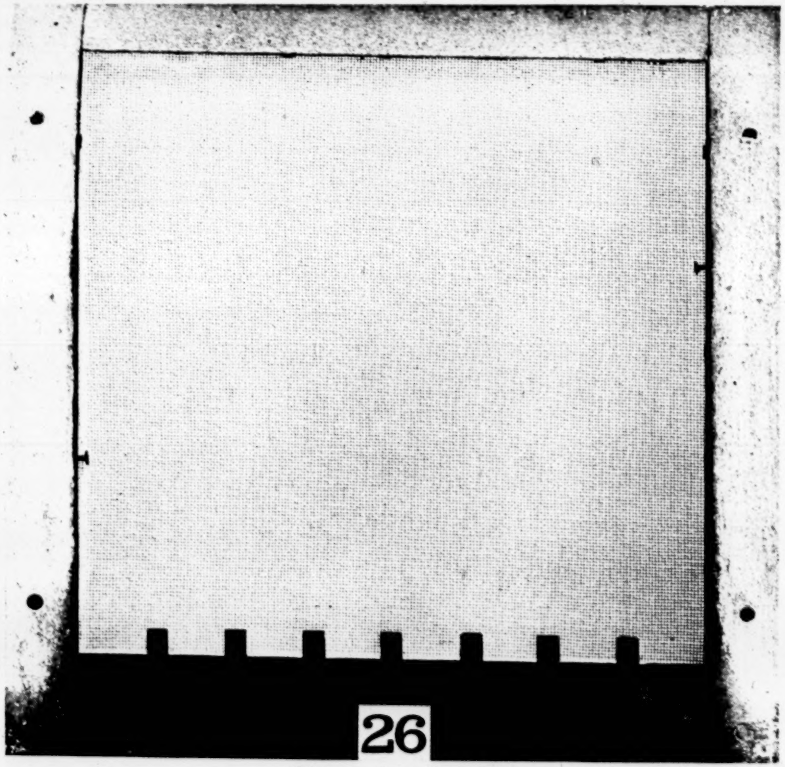
The material is badly corroded with a considerable area near the top entirely gone.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

FIG. 5.—Appearance of Material No. 5 (Copper, Unalloyed) in the 30 by 36-in. Copper Frame After 9 yr. Continuous Exposure at Pittsburgh.

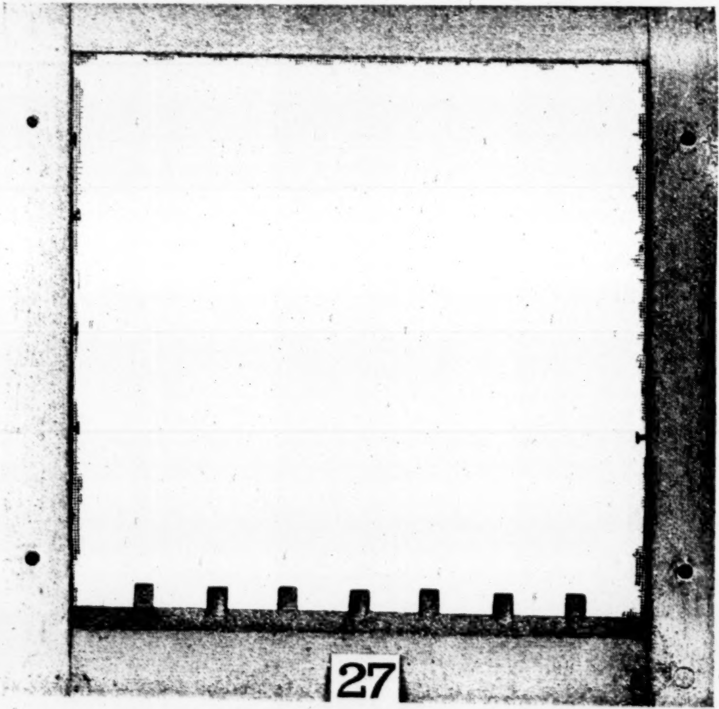
The wires near the top have corroded through in a number of places. The two larger holes in the lower left portion were caused in handling.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

FIG. 6.—Appearance of Material No. 6 (98 Copper–2 Tin) in the 12 by 12-in. Wood Frame After 9 yr. Continuous Exposure at Pittsburgh.

A few of the wires at the top right corner are corroded through.



Photograph by the U. S. Bureau of Mines, Pittsburgh, Pa.

FIG. 7.—Appearance of Material No. 7 (95 Copper–5 Aluminum) in the 12 by 12-in. Wood Frame After 9 yr. Continuous Exposure at Pittsburgh.

The material was so badly corroded that the very little which remained was easily reduced to powder by rubbing between the fingers.

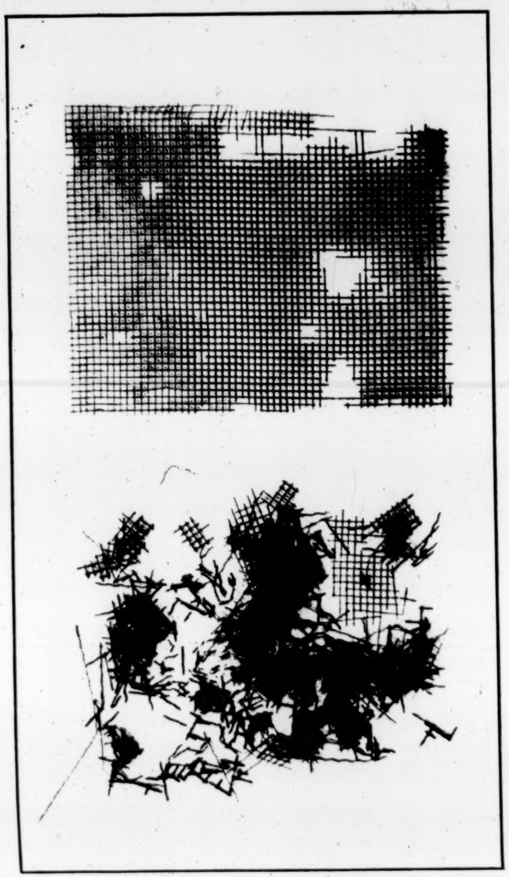


FIG. 8.—Two Equal Areas of Material No. 2 (80 Copper–20 Zinc) After 9 yr. Continuous Atmospheric Exposure at Pittsburgh.

One of the pieces has been crushed in the hand to show the extreme brittleness of the material.

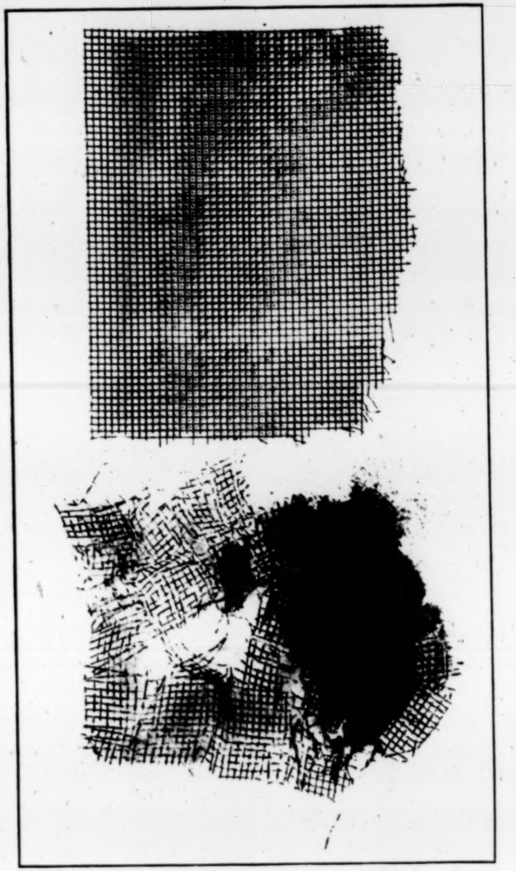


FIG. 9.—Two Equal Areas of Material No. 3 (75 Copper–20 Nickel–5 Zinc) After 9 yr. Continuous Atmospheric Exposure at Pittsburgh.

One of the pieces has been crushed in the hand to show the extent of corrosion.

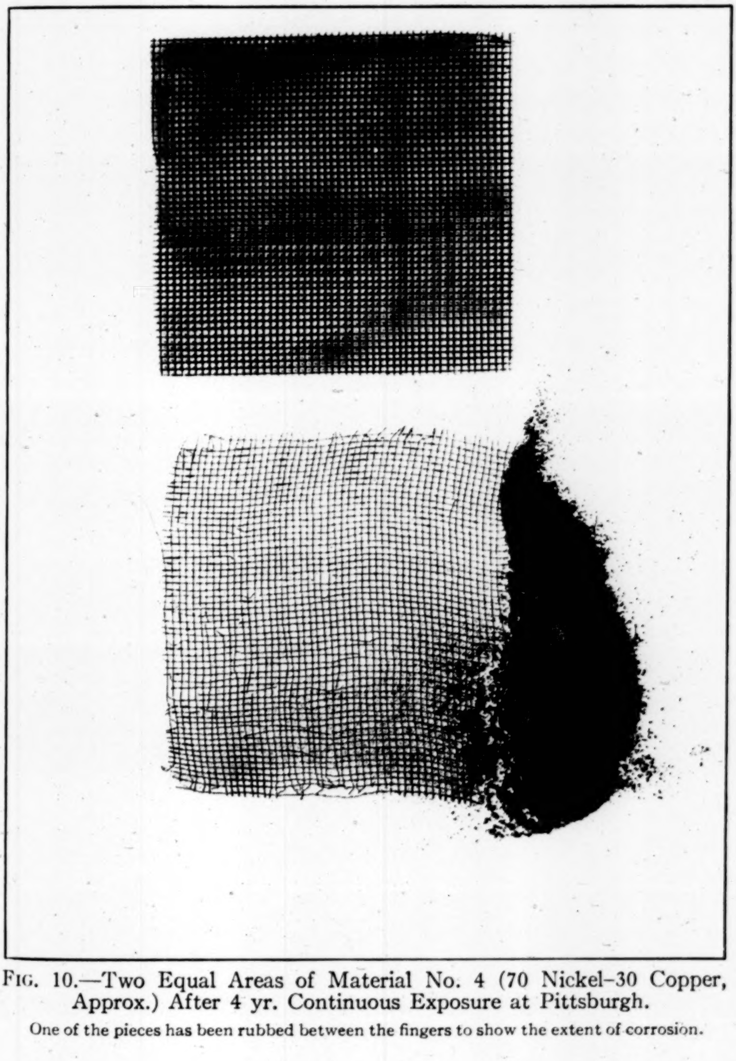


FIG. 10.—Two Equal Areas of Material No. 4 (70 Nickel–30 Copper, Approx.) After 4 yr. Continuous Exposure at Pittsburgh.

One of the pieces has been rubbed between the fingers to show the extent of corrosion.

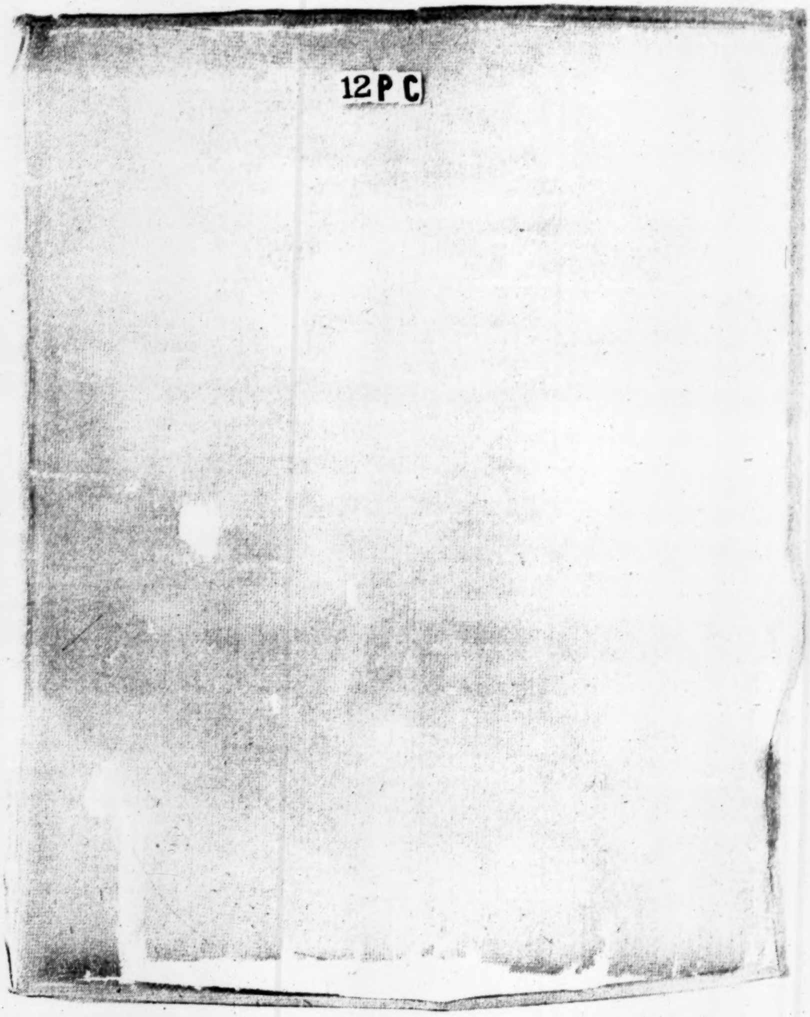


FIG. 11.—Appearance of Material No. 2 (80 Copper–20 Zinc) from the 30 by 36-in. Copper Frame After About 6 yr. Continuous Exposure at Cristobal.

The material is extremely brittle and contains a great many holes.

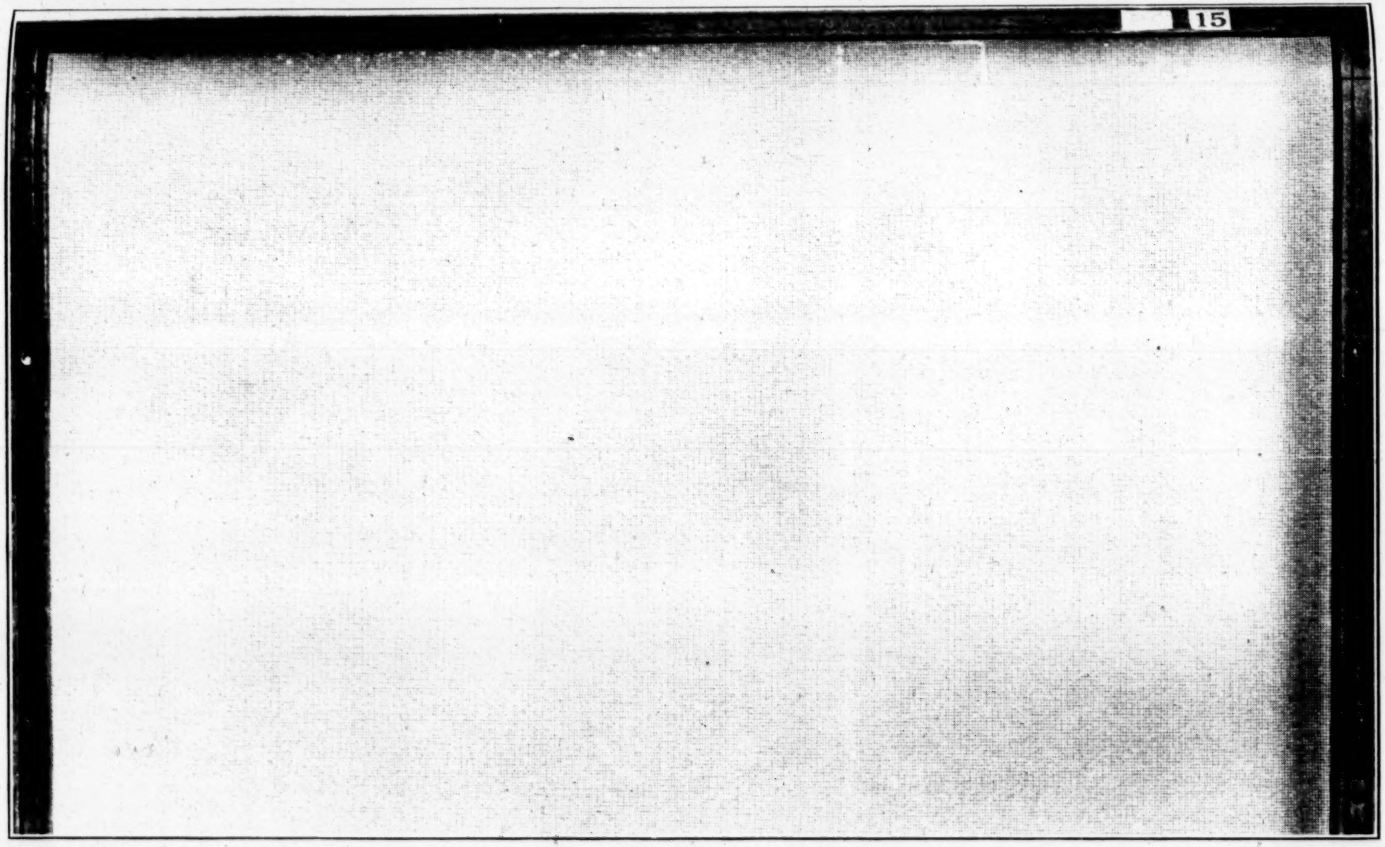


FIG. 12.—Appearance of Material No. 5 (Copper, Unalloyed) in the 30 by 36-in. Copper Frame After 9 yr. Continuous Exposure at Cristobal.

Note the two distinct bands of corrosion products extending across the screen at right angles to each other, and occasional spots of similar products distributed over the entire area. The apparent tear near the top was made with shears.

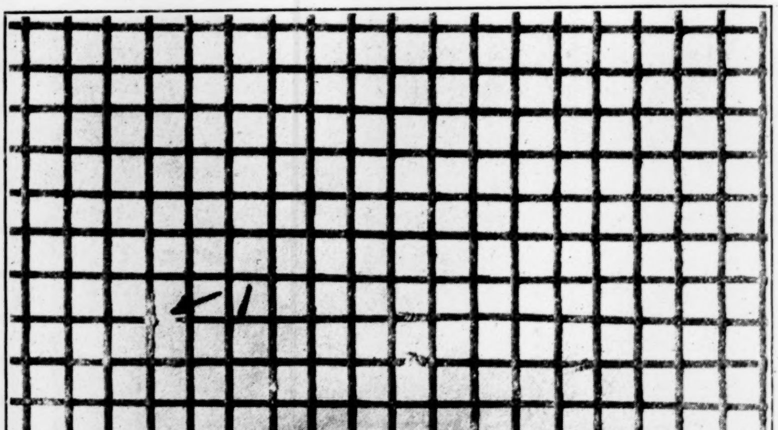


FIG. 13.—A Small Area from One of the Bands of Corrosion Products Shown in Fig. 12.

Arrows 1 and 2 show a broken and a thin wire, respectively, revealed by the removal of corrosion products. Arrow 3 indicates one of the larger deposits under which the wire was found to be corroded through.

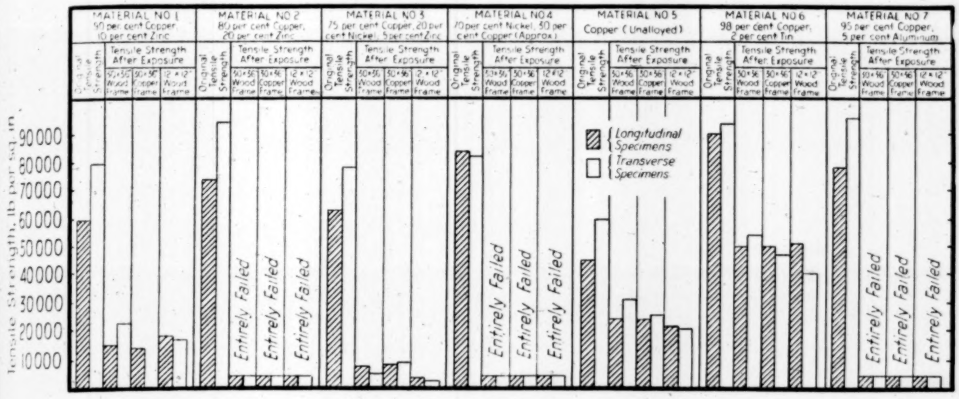


FIG. 14.—Average Results of the Tension Tests of the Longitudinal and of the Transverse Specimens of the Material Before and After Exposure at Pittsburgh.

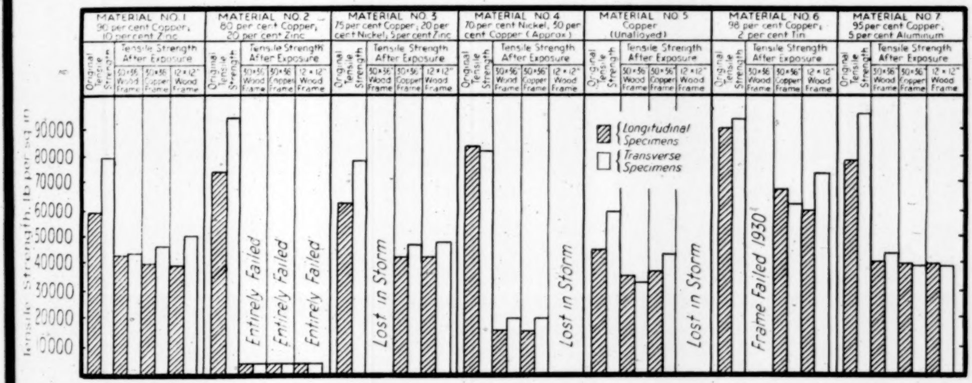
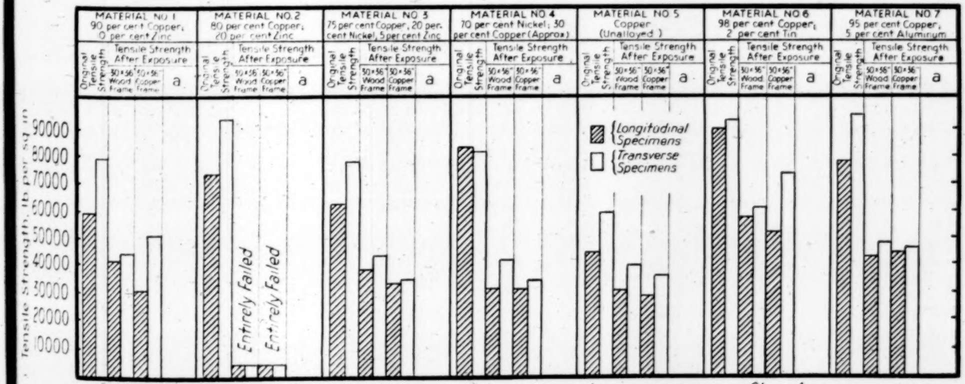


FIG. 15.—Average Results of the Tension Tests of the Longitudinal and of the Transverse Specimens of the Material Before and After Exposure at Portsmouth.



[a] The 12×12" wood frames were destroyed in some unknown manner after 4 yr. exposure.

FIG. 16.—Average Results of the Tension Tests of the Longitudinal and of the Transverse Specimens of the Material Before and After Exposure at Cristobal.

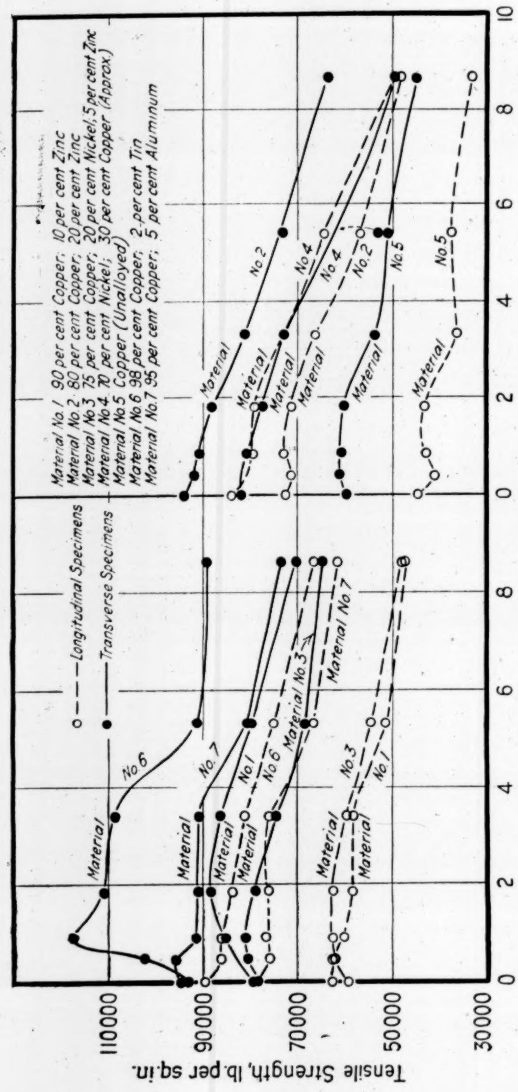


FIG. 17.—Results of Tension Tests, at Intervals Throughout the Exposure Period, on Longitudinal and Transverse Specimens of Extra Material Exposed at Washington.

The averaged results of the tension tests of specimens of the materials, before and after exposure for approximately 9 yr. at Pittsburgh, Portsmouth, and Cristobal are shown in Figs. 14, 15 and 16. The value for the tensile strength of each of the uncorroded materials is the average for 5 specimens for each direction.

Materials Nos. 2, 4 and 7 at Pittsburgh and material No. 2 at Portsmouth and Cristobal were either entirely gone or so badly corroded at the end of the exposure period that the strength could not be measured.

At Washington, where no failures have occurred in any of the framed materials, tension tests have been made at intervals throughout the 9-yr. exposure period on longitudinal and transverse specimens of the extra materials. The results are shown in Fig. 17. No explanation is suggested for the increased strength of the transverse specimens of materials Nos. 1 and 6, during the early part of the exposure period.

The average tensile strength of each material, in its original condition and at the end of the exposure period, at each of the four stations, is shown in Fig. 18, the values given being the averages of the tensile strengths of the longitudinal and the transverse specimens.

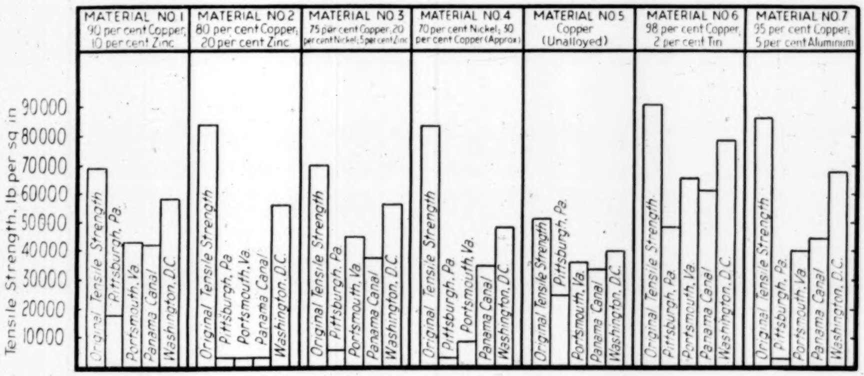


FIG. 18.—Average Results of Tension Tests on all specimens (both Longitudinal and Transverse) of each Material Before and After Exposure at each of the Four Exposure Locations.

The results of the laboratory accelerated corrosion tests that had previously been made showed no consistent correlation with the results of the atmospheric exposure tests at any of the locations. The details of these laboratory tests, which consisted in determinations of loss of weight caused by (1) exposure to salt spray, (2) by intermittent immersion in dilute sulfuric acid, and (3) by intermittent immersion in sodium chloride solution, have previously been given.[1] Likewise, the determinations of loss of tensile strength caused by exposure to salt spray have been published.[2]

The percentage loss of tensile strength after 500 hr. exposure to salt spray and corresponding changes after approximately 9 yr. exposure at each of the four locations are given for each material in Table V. In Table VI, the materials are listed, by designation numbers, in the order of increasing percentage loss of tensile strength after exposure at the four locations and in salt spray.

It is evident from these tables that the salt spray test cannot be used as a basis on which to predict the behavior of the materials at the exposure stations. The same was true for the other laboratory tests. Likewise, the behavior of the materials could not be correlated with the results of the determinations of the sulfur dioxide content of the atmosphere at the four locations.[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 492 (1926).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 864 (1930).

Table V.—Percentage Loss of Tensile Strength After Approximately 9 yr. Exposure at the 4 Locations; and After 500 hr. in the Salt Spray.[a]

Designation of Alloy	Nominal Composition, per cent	Loss in Tensile Strength After Exposure, per cent				
		At Pittsburgh, Pa.	At Portsmouth, Va.	At Cristobal, C. Z.	At Washington, D. C.	500 hr. in Salt Spray
No. 1	90 copper, 10 zinc	75	37	39	16	74
No. 2	80 copper, 20 zinc	100	100	100	33	87
No. 3	75 copper, 20 nickel, 5 zinc	92	36	47	20	[b]
No. 4	70 nickel, 30 copper (approx.)	100	90	59	43	10
No. 5	Copper (unalloyed)	51	29	34	21	33
No. 6	98 copper, 2 tin	47	28	32	13	23
No. 7	95 copper, 5 aluminum	100	54	48	22	41

[a] The data in this table were taken, for the four exposure stations, from Figure 18; for the salt spray from the 1930 Report of Committee D-14.

[b] Negligible after 5000 hr.

Table VI.—Materials Listed by Designation Numbers in the Order of Increasing Percentage Loss of Tensile Strength After Exposure at the Four Locations and in Salt Spray.

Pittsburgh, Pa.	Portsmouth, Va.	Cristobal, C. Z.	Washington, D. C.	Salt Spray
6	6	6	6	3
5	5	5	1	4
1	3	1	3	6
3	1	3	5	5
7[a]	7	7	7	7
2[a]	4	4	2	1
4[a]	2	2	4	2

[a] Material Nos. 7, 4 and 2 failed completely in the following order: No. 4, first; No. 2, next; and No. 7, next.

SUMMARY

In the mildly corrosive atmosphere at Washington, no failures occurred in any of the materials during the approximately 9-year period.

In the temperate and tropical seacoast atmospheres of Portsmouth and Cristobal, with some industrial contamination at both exposure stations, there was more damage to each material than at Washington.

The severest damage to each material was caused by the heavy industrial atmosphere at Pittsburgh.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 864 (1930).

REPORT OF COMMITTEE D-17
ON
NAVAL STORES

Subcommittee I on Viscosity of Rosin (C. E. Kinney, chairman) has continued its work during the year. A number of conferences have been held with members of the subcommittee and with the Special Committee on Softening Point Test, appointed by Committee E-1 on Methods of Testing to adapt the ring-and-ball method to asphalts, tars, pitches, rosins, and resins, both artificial and synthetic. Progress has been made in these studies and a proposed Method of Test for Softening Point by Ring-and-Ball Method has been prepared by the Special Committee which appears to be satisfactory for use in determining the softening point of rosin.

The chairman of the subcommittee has also done considerable preliminary work in attempting to apply the falling-ball viscosity method to rosin. The data so far obtained indicate that:

1. The falling-ball method is capable of differentiating between rosins having nearly identical ring-and-ball melting points.

2. As far as reproductibility of results and ease of manipulation are concerned, the falling-ball method is not as good as the ring-and-ball method.

The temperature of 100 C. was selected because it was thought that boiling water would provide the simplest and most convenient constant temperature bath. However, the effect of slight temperature variations was found to be great since the viscosity-temperature curve for most rosins is very steep at 100 C. A variation of 0.1 C. may produce a variation of 5 per cent in viscosity; a variation of 3 mm. in barometric pressure will produce a variation of more than 0.1 C. in the boiling point of water. No determinations were made at temperatures much different from 100 C.

3. The manipulations involved in the falling-ball viscosity method render it impractical for use in control and routine work on rosin.

The subcommittee does not believe that this method can be developed to a stage where it can replace methods like the ring-and-ball, etc. With more elaborate facilities for temperature control, however, this method offers one of the most convenient means for determining the viscosity of rosins at 100 C. and above, in special and research work. The subcommittee is not planning any further work on this method.

The chairman of Subcommittee I recommends that work on the softness or viscosity of rosin at ordinary temperatures be undertaken.

Subcommittee IV on Acid and Saponification Numbers and Unsaponifiable Matter (R. C. Newton, chairman) has done cooperative work during the year, but the results from different cooperators vary so widely that no formal report will be made at this time. The chairman of the subcommittee is attempting to determine why the results differ so greatly.

This report has been submitted to letter ballot of the committee which consists of 21 members; 13 members returned their ballots, of whom 12 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

F. P. VEITCH,
Chairman.

C. F. SPEH,
Secretary.

REPORT OF COMMITTEE D-19
ON
WATER FOR INDUSTRIAL USES

Considerable progress on its program has been made by Committee D-19 on Water for Industrial Uses. The various features of the work being carried on by the committee were discussed in its 1934 annual report[1] and in a progress statement in the A.S.T.M. *Bulletin*, January, 1935, p. 17. Although no meetings of the committee were held during the year, certain matters have been handled by correspondence.

No action has yet been taken by the committee in the formation of a subcommittee to undertake the preparation of specifications for and methods of testing water conditioning chemicals and materials. The Subcommittee on Methods of Sampling is presenting for information a report, appended hereto, entitled "Problems in the Standardization of Methods for Sampling Water for Industrial Purposes."

The Editorial Subcommittee is reporting progress on its work as reported to the Society in 1934. It has edited the report submitted by the Subcommittee on Methods of Sampling. The Subcommittee on Methods of Analysis, in addition to continuing the program referred to last year, has submitted to Committee D-19 four methods of analysis, which include the carbonate, hydroxide, phosphate, and sulfate ions.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Policy and Procedure (F. N. Speller, chairman).—This subcommittee has recommended holding in abeyance the formation of a subcommittee to formulate specifications and methods of test for zeolites. This recommendation was adopted pending the publication of the report of one of the subcommittees of the American Water Works Association, which had this problem in hand last year. It is anticipated that the report of the latter subcommittee will be made available late in the spring of 1935.

Subcommittee II, Editorial (E. P. Partridge, chairman).—Progress has been reported by this subcommittee on interpretations, but the material is not ready for publication. The subcommittee has condensed and edited the report on sampling prepared by Subcommittee III and recommends the publication of the report in its present form, as appended hereto, for information only.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 551 (1934).

Subcommittee III on Methods of Sampling (R. E. Hall, chairman).—The chairman of this subcommittee prepared a lengthy report, on "Problems in the Standardization of Methods for Sampling Water for Industrial Purposes." The report is based on valuable suggestions contributed by members of Subcommittee III. The essential purpose of the report is to focus attention on the fundamental problems in connection with the important subject of sampling. The report in its condensed form as edited by Subcommittee II is appended hereto and should be considered as an outline which will serve as a guide to cover the subject in all of the industrial fields where sampling and analysis of water are required. The subcommittee recommends that the edited report be published for information only at this time, so that valuable suggestions and comments may be obtained from the membership of the Society.

Subcommittee IV on Methods of Analysis (C. H. Fellows, chairman).—Subcommittee IV reports progress on the problems referred to in the 1934 report,[1] and in the statement published in the January, A.S.T.M. *Bulletin*. This subcommittee has referred to Committee D-19 methods of analysis of four ions, the carbonate, hydroxide, phosphate, and sulfate, when these ions are present in boiler feed water or boiler water supplies. These methods were developed by the Subcommittee on Water Analysis of the Joint Research Committee on Boiler Feed Water Studies, and together with supporting research data they have been previously published.[2] The methods will be referred for editing to Subcommittee II, and when made available in A.S.T.M. form will be submitted to the Society for publication as information. One meeting of the subcommittee was held during the year, at Atlantic City, N. J., in June, 1934.

This report has been submitted to letter ballot of the committee, which consists of 29 members; 25 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf the committee,

MAX HECHT,
Chairman.

R. E. HALL,
Temporary Secretary.

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[1] *Loc. cit.*

[2] "Determination of Carbonate, Phosphate, and Hydroxide in Boiler Waters," Reports of the Subcommittee on Water Analysis, Joint Research Committee on Boiler Feed Water Studies, 1933. Published in book form by American Society of Mechanical Engineers.

W. C. Schroeder, "Direct Titration of Sulphate. Tetrahydroxyquinone as an Internal Indicator," ***Industrial and Engineering Chemistry***, Analytical Edition, Vol. 5, pp. 403–406 (1933).

APPENDIX

PROBLEMS IN THE STANDARDIZATION OF METHODS FOR SAMPLING WATER FOR INDUSTRIAL PURPOSES[1]

Standardization of methods for the examination of water supplies is no new activity. Cooperative effort over a period of many years has resulted in the successive editions of "Standard Methods of Water Analysis," published jointly by the American Public Health Association and the American Waterworks Association, the recognized manual on the subject. Covering the requirements of its own field admirably, this manual is less adequate for industrial use. The need for standards applicable to boiler-water control and the belief that industry in general would profit by standards broad enough to cover most of the technological uses of this universal material led to the organization by the American Society for Testing Materials of Committee D-19 on Water for Industrial Uses.

Sampling, analysis and interpretation of analytical data must all be considered before standards can be written even in preliminary form. To stimulate discussion on the first of these subjects the present report is offered.

SYSTEMS OF CLASSIFICATION FOR THE SAMPLING OF WATER

The problems encountered in sampling water differ with its physical state, its mode of occurrence, and the objective for which the sample is procured.

Classification by Physical State:

At one time or another it may be desirable to procure samples of water in any one of the three physical states, solid, liquid or vapor, or mixtures of solid and liquid or of liquid and vapor in which it may occur. Not only must a wide range of temperature be considered but also a wide range of pressure from below that of the atmosphere up to the very high pressures now employed in industry.

Classification by Mode of Occurrence:

In most cases it is possible to classify a source of water either as unconfined or confined, although no hard and fast line can be drawn. In general, rivers, lakes, reservoirs, oceans, and even open wells, underground streams, springs and open tanks or similar industrial equipment may be considered as unconfined sources, while pipelines, closed tanks, boilers, and similar industrial equipment may be considered as confined sources. Some distinction is, perhaps, desirable between essentially quiescent and circulating water.

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[1] This report has been condensed and edited by E. P. Partridge, chairman of Subcommittee II Editorial, from a report prepared by R. E. Hall, chairman of Subcommittee III on Methods of Sampling, of Committee D-19 on Water for Industrial Uses of the American Society for Testing Materials.

Classification by Objective of Sample:

Water accumulates to a greater or lesser degree all types of material–dissolved gases, inorganic and organic substances, both in solution and in suspension, and living organisms. The possible number of constituents in water is almost legion. The variation in quantity may be a thousandfold or hundreds of thousandfold. For one purpose a trace of a particular constituent may have no significance, while in another case it is more important than other constituents present in much larger quantity.

Since for any specific purpose certain properties of the water are important, the method of sampling must be chosen to yield adequate knowledge concerning the important constituents. Both the quantity of the sample and the treatment accorded it will depend, for example, upon whether it is to be subjected to a chemical analysis, a bacterial count or a determination of turbidity.

SAMPLING PROBLEMS UNDER VARIOUS CONDITIONS

A few illustrations will indicate the complex factors involved in an attempt to develop standard methods.

Unconfined Sources:

Large bodies of water, as the ocean or the Great Lakes, are relatively constant in composition. Changes in the composition of water from wells occur usually in long swings and not abruptly. Rivers, streams, and pools, however, mirror the caprices of the atmospheric conditions around them.

To obtain a reasonably accurate estimate of the composition of large bodies of water far enough from the shore line to avoid variations due to inflowing tributaries or shore contaminations, individual samples taken at rather infrequent intervals will suffice. For a reasonable estimate of the composition of a stream or pool, however, it is essential that great care be exercised that the sample be representative of the main body of water (if it is the purpose to establish the composition of the main body, and not local conditions in any particular spot) and that samples be collected at short intervals. If the end desired is a reasonably accurate knowledge of the average composition, it is good practice to collect samples of a standard size, which are transferred to a container of sufficient capacity to receive these samples for a period of a week or more, at the end of which the composite sample is thoroughly mixed. Obviously, the large container must be given good care, and components which are subject to volatilization or change by standing must be determined on the fresh small samples before deterioration occurs. Composite sampling and testing of this sort is practiced in the water-supply departments of many cities, in the work of the Geological Survey in determining the composition of American lakes and rivers, and in many power plants.

Altogether different factors must be considered in developing standard methods for obtaining samples at a considerable depth as contrasted with surface samples. In the latter case the effect of natural currents, wind, living organisms, and surface drainage must be taken into account. While currents and submerged springs also may be important in deep sampling, the greatest problem is to prevent admixture of the sample at the desired depth with water between that point and the surface. Stratification, involving changes in mineral or oxygen content, or pH value with depth, may be very appreciable in many cases.

Confined Sources:

Water flowing in a pipe line from a supply to a point of discharge without recirculation may undergo changes in composition necessitating intelligent application of sampling methods. For example, corrosion or the effect of corrosion-inhibiting additions to the water may be indicated by changes in pH value, or in dissolved oxygen, carbon dioxide, or iron content.

Contamination of water as a result of cross-connections may involve detective ability of a high order combined with careful sampling technique. In power plants where service lines containing hard water are cross-connected with those containing soft boiler feed water to insure certain supply of water to the boiler, frequently the hard water gets into the soft water. The celebrated case of disease contamination flowing back into the service lines of a hotel in Chicago during the World's Fair illustrates how proper choice of sampling and testing can solve difficult problems.

In considering water confined in tanks or vessels, some distinction is perhaps desirable between essentially quiescent as compared with circulating water. In the former class are sumps or tanks for condensate, often cement-walled or cement-washed, the contents of which must be sampled for contamination; tanks or sumps for clarification by settling, such as those used in the intermittent lime-soda process, and those for clarification with coagulation by alum or otherwise; tanks for acid treatment with their necessary determinations of CO_2 and pH value; and tanks for artificial ice manufacture. Under the head of circulating water is included much of the equipment of power, chemical and other industrial plants.

For illustrative purposes the different conditions of pressure will be considered with reference to a power plant.

Normal pressure may be assumed to exist in the boiler feed-water lines up to the feed-water pump, since the water system pressure up to this point is slight as compared with the pressures that follow. In the hot process softener the sample may be taken before the filter or after the filter, as desired. In the cold continuous softener the sample may be taken at similar points or it may be taken farther along after the water has been heated and the control thus made on the hot water. The choice of point of sampling may make a huge difference in the treatment applied at the softener. In the equipment up to the boiler feed pump separation of oxygen is obtained, and careful choice of both the point of sampling and method of sampling of heater and deaerating heater are necessary to insure proper protection for the boiler. Sampling of the gravity return hot water and steam heating systems, as well as of systems for the acid treatment of feed water and recirculation of the boiler water to provide safe pH values also is done essentially at normal pressure. In the part of the boiler layout extending from the condensers back to the ordinary feed water, sampling of the condenser cooling water and testing for condenser leakage are desirable.

Subnormal pressure is encountered in vacuum heating systems where the condensate must be tested especially at various points in the vacuum return line. Attention must be given in sampling as to whether the sample has been condensed from and in contact with the steam, or represents totally condensed steam. For instance, in taking a sample of steam for oxygen concentration, the steam line is tapped, steam is removed through a coil which passes through a cooling chamber, and the condensate coming from the coil is tested for its oxygen. This represents truly the amount of oxygen in the steam. In corrosion problems, however, the important consideration is the amount of oxygen in the water that condenses from the steam and in contact with the steam inside the lines, a totally different proposition, because the partial pressure of oxygen in the steam is so slight that for all practical purposes none of it will be dissolved in the condensate. It frequently happens that one set of tests sampled in one way will show that the condensate is of a corrosive nature because of its dissolved oxygen content and relatively low pH value, while another set sampled by the other method will find a higher pH value and no oxygen.

Positive pressure exists in the boiler, which presents varying problems as a result of mechanical differences.

The cross-drum type is perhaps as common as any today. Correct sampling of the boiler water requires careful attention to the location at which samples are taken, since these may consist in part of condensate or in part of feed water. The concentration has been seen to vary immensely from one end of a drum to the other with different conditions of feed-water entry. In the drum itself there is a difference in concentration between the water which is in the main part of the drum and that which is separated from the main part of the drum by the ordinary curtain baffle. Samples taken from the mud drum are different from those taken from the main drum; samples taken in the upper boiler tubes at their discharge end into the steam header are different from those taken in the mud drum; samples taken in a boiler with overdeck superheaters will show different results from samples taken where the superheater is interdeck; samples taken during or after high-rating operation show different concentrations from samples taken during low-rating operation. The pressures of these types of boilers vary from normal atmospheric to 1450-lb. pressure in this country, and appropriate sampling without flashing requires special equipment.

Varying conditions frequently require tests on the steam, on mixtures of the steam and condensate, or on mixtures of the steam and boiler water for oxygen, alkalinity, sulfate, chloride, etc. When the purity of steam is checked by means of the calorimeter, by conductivity or by chemical analysis, the method and point of sampling are of extreme importance.

DEVELOPMENT OF STANDARD METHODS

The great diversity of conditions under which water samples must be procured has been indicated in the preceding section. It is obvious even from this very incomplete discussion that specifications cannot be drawn for sampling methods which will be applicable in all cases. There will always be need for the exercise of trained judgment in the procurement of samples. It should be possible, however, on the basis of experience in many specific individual cases, to develop broad general rules as a guide for the sampling of water under various industrial conditions, remembering the three cardinal points of all sampling:

1. A sample at the moment it is taken must represent the conditions in the material, or in the particular location in the material, from which it is removed;
2. Manipulation from the moment of sampling to the moment of analysis must be safeguarded against changes in the properties which are to be determined;
3. Samples must be adequate to permit accuracy of analysis of the same order as the accuracy of sampling, and sufficiently precise for the objective in view.

Subcommittee III on Methods of Sampling of Committee D-19 on Water for Industrial Uses will appreciate the cooperation and criticism of all persons interested in the sampling of water. These should be addressed to the chairman of Subcommittee III, Mr. R. E. Hall, 304 Ross St., Pittsburgh, Pa.

REPORT OF COMMITTEE E-1
ON
METHODS OF TESTING

While a meeting of Committee E-1 on Methods of Testing has not been held since the meeting at Atlantic City, N. J., in June, 1934, a number of the sections of the technical committees met in connection with the Spring Group Meetings of A.S.T.M. Committees in Philadelphia in March. A meeting of Committee E-1 will be held at this annual meeting subsequent to the presentation of this report to the Society.

The work of Committee E-1 during the past year has largely been concentrated in its various technical committees. The sections of the Technical Committee on Mechanical Testing have been particularly active in connection with various problems dealing with the test matters under their jurisdiction. This has resulted in several recommended revisions in existing tentative standards. Considerable progress has also been made by the Special Committee of the Technical Committee on Consistency, Plasticity, Etc., in the development of an improved method of test for softening point (ring-and-ball method) while one section of the Technical Committee on Particle Size and Shape is considering a new test method and another has completed an extensive revision of an existing standard specification. Certain of these various proposals which are discussed in detail later in this report are expected to be presented to the Society for publication as tentative subsequent to the annual meeting through Committee E-10 on Standards.

The Executive Committee of the Society appointed three representatives-at-large to serve on the Advisory Committee, namely, D. E. Douty, United States Testing Co., and the reappointment of T. A. Boyd of the General Motors Corp. and R. L. Templin of the Aluminum Company of America, each for three-year terms, expiring in 1937. Mr. H. W. Bearce, National Bureau of Standards, has been appointed chairman of the Technical Committee on Methods for Density and Mr. T. Smith Taylor has been appointed as chairman of the Technical Committee on Volatility to succeed E. W. Dean, resigned.

The conference group mentioned in last year's report,[1] that was appointed to give consideration to methods of designating chemical, physical and similar specification requirements in the standards of the Society, recommended that this work be undertaken by a technical committee of Committee E-1. The organization of the new technical committee, designated Technical Committee XI on Designation and Interpretation of Numerical Requirements, has now been completed with the following personnel:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 553 (1934).

J. A. Gann, *Chairman,* The Dow Chemical Co.
H. F. Dodge, *Secretary,* Bell Telephone Laboratories
H. V. Churchill, Aluminum Co. of America
Anson Hayes, The American Rolling Mill Co.
H. F. Moore, University of Illinois
E. F. Kenney, representing Committee A-1 on Steel
G. E. F. Lundell, representing Committee A-3 on Cast Iron
L. W. Hopkins, representing Committee A-5 on Corrosion of Iron and Steel
W. A. Cowan, representing Committee B-2 on Non-Ferrous Metals and Alloys
J. L. Christie, representing Committee B-5 on Copper and Copper Alloys
J. A. Gann, representing Committee B-7 on Light Metals and Alloys
P. H. Bates, representing Committee C-1 on Cement
F. B. Lysle, representing Committee C-3 on Brick
A. E. R. Westman, representing Committee C-8 on Refractories
H. W. Leavitt, representing Committee C-9 on Concrete and Concrete Aggregates
S. H. Ingberg, representing Committee C-10 on Hollow Masonry Building Units
D. W. Kessler, representing Committee C-18 on Natural Building Stones
A. T. Goldbeck, representing Committee D-4 on Road and Paving Materials
W. A. Selvig, representing Committee D-5 on Coal and Coke
S. R. Church, representing Committee D-7 on Timber
L. T. Sutherland, representing Committee D-9 on Electrical Insulating Materials
G. E. Hopkins, representing Committee D-13 on Textile Materials
F. P. Veitch, representing Committee D-17 on Naval Stores
E. P. Partridge, representing Committee D-19 on Water for Industrial Uses

Subsequent to the 1934 annual meeting, as mentioned in the annual report last year,[1] Committee E-1 presented to the Society through Committee E-10 on Standards new Tentative Definitions of the Terms Consistency and Plasticity (E 24 – 34 T), on the recommendation of Technical Committee II on Consistency, Plasticity, Etc.; also revisions of the Tentative Specifications for Verification of Testing Machines (E 4 – 33 T), recommended by Technical Committee I on Mechanical Testing. The new definitions and the revised Methods E 4 – 34 T were accepted for publication as tentative[2] by Committee E-10 at a meeting held on August 22, 1934, and appear in the 1934 *Proceedings.*[3]

Later in the year, on the recommendation of Technical Committee I, the committee presented[2] to the Society through Committee E-10 revisions of the Tentative Methods of Impact Testing of Metallic Materials (E 23-33 T), which were accepted for publication on November 15, 1934, and appear in the 1934 *Proceedings.*[1]

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 34, Part I, pp. 557, 558 (1934).

[2] In submitting these recommendations to Committee E-10 on Standards, Committee E-1 reported the following results of the letter ballot vote of a total of 42 ballots returned from a committee membership of 57: Tentative Definitions of Terms Consistency and Plasticity (E 24 – 34 T), 30 affirmative, 1 negative and 11 ballots marked "not voting"; Tentative Methods of Verification of Testing Machines (E 4 – 34 T), 34 affirmative, 0 negative and 8 ballots marked "not voting." On the Tentative Methods of Impact Testing of Metallic Materials (E 23 – 33 T), 32 ballots were returned all of which were affirmative.

[3] *Proceedings,* Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1245, 1233 (1934); also 1934 Book of A.S.T.M. Tentative Standards, pp. 1169, 1157.

Technical Committee I on Mechanical Testing (H. F. Moore, chairman):

During the past year the committee, through the activities of its sections, has prepared minor revisions of the Tentative Methods of Verification of Testing Machines (E 4 - 34 T) and of the Tentative Definitions of Terms Relating to Methods of Testing (E 6 - 32 T), as indicated in detail later in this report.

Section on Tension Testing (R. L. Templin, chairman).—This section held a meeting at Philadelphia in March, 1935, at which there was a discussion of the rather wide variation of conditions under which tension tests are now made. A definite attempt is under way to establish closer contact between this section and the standing committees of the Society which have tension tests included in their standards. It is hoped by this means to bring about a somewhat better degree of uniformity in making tension tests, realizing, of course, that different materials demand some considerable variation in methods if test results are to be accurate, reproducible and significant. So far, the section has not been able to make effective contact with the committees responsible for standards which include tension tests for non-metallic materials. At its meeting the section discussed the use of curved grips for tension tests of pipes and tubes, and the technique and significance of delicate tests for determining proportional limit.

Section on Compression Testing (M. F. Sayre, chairman).—This section is working on the revision of the present Tentative Methods of Compression Testing of Metallic Materials (E 9 - 33 T). It has found that before satisfactory changes can be made further study of the effect of speed of testing is necessary, and the section is keeping in close touch with the Section on Effect of Speed of Testing which is working on this important and complex problem.

Section on Bend Tests for Ductility (A. B. Kinzel, chairman).—This section is engaged in the development of tentative standards for bend tests for the ductility of thin sheet metals, and is working in cooperation with the Section on Testing of Thin Sheet Metals.

Section on Indentation Hardness (J. R. Townsend, chairman).—This section held a meeting at Philadelphia in March, 1935, at which the principal item of discussion was the preparation of standard test blocks for use in calibrating hardness testing machines, especially Rockwell machines. It was reported by a representative of the National Bureau of Standards that it seemed feasible to develop a system of standardizing test blocks in which the hardness of a standard block should be reported in terms of length, mass and time—fundamental units. It may be noted that Brinell hardness numbers are stated in such units. The cost of developing such a system of standardization of test blocks was discussed, and it was estimated that to attack the problem promptly, a fund of $3000 should be provided, mainly for the salary of a research assistant. A letter ballot is in progress to ascertain the formal judgment of the members of the section on the importance and probable satisfactoriness of such standardization of test blocks.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 34, Part I, p. 1201 (1934); also 1934 Book of A.S.T.M. Tentative Standards, p. 1118.

The standardization of hardness tests other than the Brinell and the Rockwell was discussed, but so far there seems to be no great demand for such standardization.

Section on Testing Thin Sheet Metals (C. H. Marshall, chairman).—This section held a meeting at Philadelphia in March, 1935, at which time it was reported that the questionnaire, which was planned at the meeting last June, had been distributed. This questionnaire seeks information on the use, limitations, and significance of various tests used on thin sheet metals. At the meeting, arrangements were made for closer cooperation with the Sections on Tension Testing, on Indentation Hardness, and on Bend Tests for Ductility. A round-table discussion on Ductility Testing of Sheet Metals is being held during the current annual meeting of the Society under the sponsorship of this section in cooperation with the Section on Bend Tests.

Section on Flexure Tests (H. F. Clemmer, chairman).—At its first meeting which was held in June, 1934, at Atlantic City, N. J., this section decided to undertake as its first problem a study of the effect of span-depth ratio on flexure strength. Members of the section were assigned to the study of the effect of this ratio for concrete, cast iron, building stone, brick, gypsum products, refractories, timber and electrical insulating materials. This study is now in progress, and data are being gathered from various laboratories.

Section on Impact Testing (W. W. Werring, chairman).—The section held a meeting in June, 1934, at Atlantic City at which time various minor revisions of the Tentative Methods of Impact Testing of Metallic Materials (E 23 – 33 T) were discussed and approved for submission to letter ballot of the section. The changes proposed represented an improvement in the testing requirements and resulted from a year's use of the methods. As mentioned earlier in this report, the revisions were presented to the Society through Committee E-10 on Standards and the revised methods were accepted for publication as tentative.

The question of limits of accuracy and of methods of machining notches in specimens was discussed. Data are being gathered as to the effect of variation of shape and dimensions of notch in different metals.

The failure of notched specimens of ductile metals to give clean, sharp fractures in the Charpy or Izod impact flexure test was discussed, and the impact tension test was suggested as having advantages over the flexure test for such metals. However, it was recognized that much more study of the impact tension test would be necessary before any standardization of it would be feasible.

Section on Effect of Speed of Testing (P. G. McVetty, chairman).—This section is facing the difficult problem that to insure satisfactory control of speed of testing it is *rate of strain* which must be controlled, and that controlling the speed of head of the testing machine does not control rate of strain accurately, especially below the yield strength of metallic materials. It seems probable that the physical properties of most non-metallic materials are more seriously affected by variation in rate of strain than are metallic materials, and that brittle metals are more affected than are ductile metals. Two investigations seem desirable: (*1*) a careful study of effect of rate of strain on the mechanical properties of a wide variety of materials, and (*2*) the development of practical means for insuring that a test of a specimen may be run at a controlled and predictable rate of strain. The section is studying the available data on effect of speed of testing, but is seriously handicapped by the fact that in most studies of the effect of speed of testing only the speed of head of machine is recorded.

Section on Calibration of Testing Machines and Apparatus (H. F. Moore, chairman).—The section held a meeting during the spring group meetings of the Society in Philadelphia during March, 1935. At that time the following minor revisions of the present Tentative Methods of Verification of Testing Machines (E 4 – 34 T) were considered which, after approval by Committee E-1, are to be submitted to Committee E-10 on Standards so that the methods may be published in their revised form during the year.[1]

Section 2.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

(*a*) Standard Weights.—Verification by the direct application of standard weights to the weighing mechanism of the testing machine, where practicable, is the most accurate method. Its limitations are (1) the small range of load which can be covered, (2) the non-portability of any large amount of standard weights, and (3) its non-applicability to horizontal testing machines *or to vertical testing machines whose weighing mechanisms are attached to their upper platens.*

Section 3.—Change the note following this section from its present form to read as follows:

NOTE.—For any testing machine (particularly for certain types of machines in which the load-indicating device is actuated by a Bourdon pressure tube, a hydraulic (or steam-engine) indicator or other device depending on the elastic properties of a material, or for machines in which the load is measured by measuring the pressure in a hydraulic jack) the errors observed at corresponding loads taken, first by increasing the load to the test load and then by decreasing it to the test load, may not agree. Testing machines are usually used under increasing loads, but if a testing machine is to be used under decreasing loads it should be calibrated under decreasing loads as well as under increasing loads.

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[1] Subsequent to the annual meeting Committee E-1 presented these revisions to the Society, see Editorial Note, p. 496.—ED.

Section 10.—Change the note following this section from its present form: namely,

NOTE.—The method of verification by standardized proving levers is used, at the present time, only on vertical testing machines. It is often used up to loads of 10,000 lb.

to read as follows:

NOTE.—The use of standardized proving levers on horizontal testing machines involves the use of bell crank levers. They require special methods of determination of lever ratio, which have not yet been codified in A.S.T.M. standards. Proving levers for vertical testing machines are now available up to 50,000-lb. capacity.

Section 13.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

13. (*a*) The scale of the indicating mechanism shall be uniformly graduated. The distance between any two graduation lines, dots, or other dividing marks (*or between their images, if a viewing system with a definite optical magnification is used*), shall be not less than 0.035 in.

Add a sentence to the end of Paragraph (*b*) to read as follows:

For scales on a circular dial, when successive lines are set to one fixed index line, the positions of successive graduation lines nearly diametrically opposite, referred to another fixed index line shall differ from each other by (*1*) not more than 5 per cent of the smallest division of the dial, or (*2*) not more than 0.1 per cent of the minimum load in the loading range of the instrument, if (*2*) be larger than (*1*).

Change Paragraph (*c*) from its present form: namely,

(*c*) For each division of the scale, the change in load required to change the reading from one graduation line to an adjacent graduation line shall not exceed one fifth of 1 per cent of the capacity load.

to read as follows:

(*c*) The change of load necessary to cause a relative movement of 0.1 in. between the index line and the scale (or its image if a viewing system with a definite optical magnification is used) shall not exceed 1 per cent of the capacity load of the instrument.

Section 16.—Transpose this section covering Preliminary Cyclic Loading to follow the present Section 18 on Primary Standards for Elastic Calibration Devices, renumbering these sections accordingly.

Section on Elastic Strength of Materials (F. B. Seely, chairman).—The section held a meeting at Atlantic City in June, 1934. It was found that some confusion existed in connection with the use of the term "set method" for determining yield strength when it is a deviation (offset) from Hooke's law rather than actual set, which is the criterion used in applying the method. The question of substituting another word for "set" was discussed, but it was judged better to modify the present Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 32 T) by the addition of an explanatory note. Accordingly, this section has prepared the following revisions in the notes which accompany the definition of yield strength in the Tentative Definitions E 6 – 32 T which, after approval by Committee E-1, are to be submitted to Committee E-10 on Standards so that the definitions may be published in their revised form during the year:[1]

In the note under the definition of Yield Strength add the following sentence at the end of Paragraph 1 (*b*):

> For the higher strength steels, a gage length of less than 8 in. is recommended.

Change Paragraph 2 (*a*) headed "Set Method" by the addition of the following statement:

> For any given stress the deviation (offset) from Hooke's law is only approximately equal to the set after the removal of that stress, and the approximation becomes less and less exact as the permissible deviation diminishes. This method is devised for determining a stress corresponding to a well marked plastic deformation, or set, and it is not feasible to specify a very small value for the permissible "set," *Om.*

In Paragraph 2 (*b*) headed "Approximate Method Without Stress-Strain Diagram," change the second sentence to read as follows by the addition of the italicized words and figures and the omission of the words in brackets:

> The total strain can be obtained satisfactorily by use of an extensometer [or in some cases by use of dividers particularly if the surface of the specimen is prepared so that the line made by the dividers is a fine line and if it is observed through a reading glass] *reading to 0.0001 in. per inch of gage length.*

In connection with the set method, Paragraph 2 (*b*), the following footnote should be added giving the values of permissible set which appear in existing A.S.T.M. Standards and Tentative Standards:

> Yield Strength (or its equivalent) is specified as follows in the standards and tentative standards of the American Society for Testing Materials:

STANDARDS OR TENTATIVE STANDARDS FOR:	LIMITING VALUE OF "SET," PER CENT
Alloy-Steel Pipe	0.2
Aluminum-Alloy Bars, Rods, Shapes, Sheet	
Magnesium-Base Alloy Forgings, Castings, Sheet	
The Alloy: Copper, 80 per cent; Tin, 10 per cent; Lead, 10 per cent	0.5 (elongation under load; approximately equivalent to "set" of 0.35 per cent)
Copper-Silicon Alloy Plates, Sheets, and Bars	
Malleable Iron Castings	
Sand Castings of Alloy: Copper, 88 per cent; Tin, 8 per cent; Zinc, 4 per cent	
Aluminum Bronze Castings	
Bronze Bearing Metals and Steam or Valve Sand Castings	
Composition Brass or Ounce Metal Sand Castings	
Naval Brass Rods for Structural Purposes	

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[1] Subsequent to the annual meeting Committee E-1 presented these revisions to the Society, see Editorial Note, p. 496.—ED.

Technical Committee II on Consistency, Plasticity, Etc. (E. C. Bingham, chairman):

As mentioned earlier in this report the Tentative Definitions of Terms Consistency and Plasticity (E 24 – 34 T) developed by this committee were issued as tentative in August, 1934. Since these have been published for less than a year it is recommended that they be continued as tentative as the committee is desirous of receiving constructive suggestions and criticisms respecting them.

The Special Committee on Softening Point Test (H. M. Hancock, chairman) has made excellent progress in perfecting a general method of test for softening point (ring-and-ball method) which will be applicable to asphalts, tars, pitches, rosins, and most resins both natural and synthetic. The method under consideration represents a revision of the existing Standard Method of Test for Softening Point of Bituminous Materials (D 36 – 26)[1] which was originally prepared by Committee D-4 on Road and Paving Materials. The several members of the committee undertook the necessary studies and investigative work covering various features of the apparatus and details of the test procedure. Based on these studies and after two conferences by members of the Special Committee and considerable correspondence, a proposed Method of Test for Softening Point by Ring-and-Ball Method was developed and distributed to representatives of the various interested standing committees. This draft was revised in detail at a meeting of those interested in Philadelphia in March. The suggestions received by the committee at that meeting have been incorporated in a redraft of the proposed method. This will be considered by the committee at a meeting during the current annual meeting so that the method may be presented to the Society during the summer for publication.

Technical Committee III on Particle Size and Shape (L. T. Work, chairman):

During the past year the activities of this technical committee have been centered in the work of its Sections on Sub-Sieve Sizes and on Coarse Screens, as discussed below. The committee is reviewing the Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T), developed by Committee C-1 on Cement, which was issued as tentative in December, 1934.

Section on Sub-Sieve Sizes (G. S. Haslam, chairman).—This section has made considerable progress in its cooperative series of tests on particle size measurement by the microscopic count method mentioned in the 1934 report. Various features of the proposed method have been studied by a group of eight laboratories. These studies have included a careful check of important parts of the procedure to determine where the greatest sources of inaccuracies were and to develop a procedure to eliminate them; also actual measurements of several common pigments using the proposed procedure and a correlation of the particle size test data obtained. A preliminary report has been prepared together with a detailed description of the proposed Method of Measurement of Average Particle Diameter of Sub-Sieve Particulate Substances by Dark Field Methods, both of which are appended to this report. These have also been distributed to the members of the section and to the cooperating laboratories. The section plans to review the report and proposed method at its meeting during the current annual meeting as well as to consider plans for its future work.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 984.

Section on Coarse Screens (F. H. Jackson, chairman).—As the result of certain criticisms of the Standard Specifications for Round-Hole Screens for Testing Purposes (E 17 – 33),[1] which had to do primarily with the fact that there were no tolerances on plate thickness and spacing for openings, the section has prepared a proposed revision of the specifications which introduces suitable tolerances as well as clarifies the paragraph covering space of opening so as to require a triangular spacing. The revision, which is in the form of proposed tentative specifications is appended hereto[2] and it is intended that it will supersede, when adopted as standard, the present Standard Specifications E 17 – 33. After approval by Committee E-1, the revised specifications are to be submitted to Committee E-10 on Standards so that they may be published in their revised form during the year.[3]

Technical Committee VII on Chemical Composition (G. E. F. Lundell, chairman):

This technical committee has not held a meeting during the year. There are, however, some important matters having a bearing on the work of the committee that it is desirable to report at this time.

The Subcommittees on Chemical Analysis of Committees A-1 on Steel, A-2 on Wrought Iron, A-3 on Cast Iron and analysts representing Committees A-9 on Ferro-Alloys, A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys, and B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys have been engaged during the year in revising the A.S.T.M. Standard Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 24), of Alloy Steels (A 55 – 24) and Methods of Sampling and Chemical Analysis of Pig and Cast Iron (A 64 – 27). It is proposed to combine the methods into one document covering all of these materials. Considerable progress has been made and the work will be completed before June, 1936.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1242.

[2] See p. 1289.—ED.

[3] Subsequent to the annual meeting Committee E-1 presented the revised specifications to the Society; see Editorial Note, p. 496.—ED.

As a result of a movement for the centralization of activities dealing with the chemical analysis of metals, the Executive Committee of the Society has authorized the formation of a standing committee on Chemical Analysis of Metals to replace the present subcommittees on chemical analysis now organized under the individual standing committees. It is proposed that the scope of the committee will cover both ferrous and non-ferrous metals. An organization meeting of the committee will be held during the current annual meeting.

Technical Committee VIII on Thickness Measurement (W. E. Emley, chairman):

The committee feels that the principles to be observed in measuring the thickness of resilient materials are now fairly well known and have been published in previous reports of Committee E-1. Committees D-11 on Rubber Products and D-13 on Textile Materials are now considering the possibilities of revising their testing methods so that these principles can be more closely complied with. The technical committee is, however, facing a situation where several industries have for years been using methods which violate some of these principles. These methods are so strongly entrenched that it will probably require some years of educational effort before they are revised.

Technical Committee IX on Interpretation and Presentation of Data (Anson Hayes, chairman):

During the year the committee has furnished consulting advice in regard to the use of statistical methods in the field of manufacturing and testing of products. In some of the problems on which assistance has been given, Mr. H. F. Dodge has prepared written reports on the analysis of the problem. There have been numerous cases where those having statistical problems with which to deal have been assisted in finding suitable sources of information in literature, necessary for the solution of their problems. Lectures have been given before regional meetings of the American Society of Mechanical Engineers on the use of statistical methods in the manufacture of sheet metal and on other subjects along statistical lines.

The technical committee has prepared two Supplements to the Manual on Presentation of Data (1933), as follows:

Supplement A. Presentation of ± Limits of Uncertainty of an Observed Average.[1]

Supplement B. "Control Chart" Method of Analysis and Presentation of Data.[1]

The committee recommends these supplements for publication with this report and also as a separate publication to supplement the Data Manual.

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[1] These supplements appear on pp. 1411 and 1418.—ED.

Technical Committee XI on Designation and Interpretation of Numerical Requirements (J. A. Gann, chairman):

At its organization meeting in Philadelphia on March 7, the committee considered at some length the various matters which may occupy its attention in undertaking such a comprehensive subject as indicated by its title. It appeared that the committee would need to give consideration to the proper designation or methods of expressing requirements for chemical and physical properties in standards, permissible tolerances in test procedures and interpretation of specification requirements from the standpoint of acceptance or rejection of material. These together with certain implied and associated expressions, such as sampling, number of tests, accuracy of tests, etc., include most of the material in specifications and appear to present a complex problem when viewed from the standpoint of the diversity of materials covered by A.S.T.M. specifications.

In order to guide the committee in arriving at a precise statement of its scope and activities, a subcommittee has been appointed consisting of J. A. Gann, H. F. Dodge, G. E. Hopkins, H. F. Moore, R. W. Crum, G. E. F. Lundell, and H. W. Leavitt to review existing A.S.T.M. standards regarding the designation and intent of commercial requirements.

This report has been submitted to letter ballot of the committee, which consists of 56 members; 47 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

R. E. HESS,
Ex-Officio Secretary.

EDITORIAL NOTE

Subsequent to the annual meeting Committee E-1 on Methods of Testing presented to the Society on August 22, 1935, through Committee E-10 on Standards the following recommendations:

Revision of the Tentative Methods of Verification of Testing Machines (E 4-34 T)

Revision of the Tentative Definitions of Terms Relating to Methods of Testing (E 6-32 T)

A tentative revision of the Standard Specifications for Round-Hole Screens for Testing Purposes (E 17-33)

The above recommendations were accepted by Committee E-10 and appear respectively on pp. 1303, 1315 and 1410.

REPORT ON STUDY OF MICROSCOPIC COUNT METHOD OF PARTICLE SIZE MEASUREMENT

REPORT OF SECTION ON SUB-SIEVE SIZES

The method described by Gehman and Morris[1] forms the basis for the proposed Method of Measurement of Average Particle Diameter of Sub-Sieve Particulate Substances by Dark Field Methods which accompanies this report and is appended hereto. It was found soon after the publication of the paper of Gehman and Morris that results checking within a reasonable accuracy could not be consistently obtained in different laboratories and the need was, therefore, quickly recognized of studying the important parts of the procedure in order to determine where the greatest sources of inaccuracies lay and to develop a procedure which would eliminate them.

The cooperative test work was carried out by the following active members of the committee:

R. P. Allen, B. F. Goodrich Co., Akron, Ohio.
F. H. Amon, Godfrey L. Cabot, Inc., Boston, Mass.
H. W. Catt, B. F. Goodrich Co., Akron, Ohio
E. J. Dunn, Jr., National Lead Co., Brooklyn, N. Y.
D. L. Gamble, New Jersey Zinc Co., Palmerton, Pa.
S. D. Gehman, Goodyear Tire and Rubber Co., Akron, Ohio
G. S. Haslam, New Jersey Zinc Co., Palmerton, Pa.
J. M. Jackson, V. L. Smithers, Inc., Akron, Ohio
W. J. Latimore, C. K. Williams Co., Easton, Pa.
P. P. McClellan, Firestone Tire and Rubber Co., Akron, Ohio
T. C. Morris, Goodyear Tire and Rubber Co., Akron, Ohio
C. R. Park, Firestone Tire and Rubber Co., Akron, Ohio
L. H. Willisford, Goodyear Tire and Rubber Co., Akron, Ohio

Study of Variations in Cell Depth Measurements:

The first work of the committee was to check the possible variation in measurement of cell depth when the observations are made by experienced observers. In conducting this work, standard Zeiss quartz cells were filled with a zinc oxide suspension properly enclosed in a Zeiss chamber holder. These five cells, thus assembled, were then sent in turn to each of the committee members for measurement of cell depth.

The results obtained were very unsatisfactory. From them and from the comments of the participants, two conclusions were drawn, as follows:

1. The results clearly indicated a change in the depth of the cells which apparently arose from handling, mailing and so forth.

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[1] Gehman and Morris, "Measurement of Average Particle Size of Fine Pigments," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 4, p. 157 (1932).

Measurements were made by the same observers in the same laboratory but the observations were separated by an interval of about three months; the cell depths obviously changed between the two measurements. This change over a relatively long period is of course not serious because in the ordinary course of events all measurements on a cell will be completed within a few hours. This change became serious only because of the attempted check-work of the committee.

2. In spite of the change in the depth of the cell, the results also indicated a lack of agreement between different observers.

There was a good possibility that the cells varied erratically in depth from one time to another and because the committee was not primarily interested in such variations but was primarily concerned with the problem of how close different observers in different laboratories could check each other, it was decided that this primary aim could best be accomplished by making measurements on an invariable cell. Any further work of depth measurements in liquid cells was then abandoned and the committee made up permanent solid cells as follows:

A small drop of dilute India ink was allowed to dry on the surface of a microscope slide and another on a cover glass; the cover glass was then cemented to the slide, with one drop directly over the other, by means of molten arochlor. By pressing the cover glass down while the arochlor hardened, it was possible to obtain cells in which the depth varied from 3 to 14 microns.

When a slide so prepared was examined in a dark field microscope, the top surface of the slide and the bottom surface of the cover glass could be readily located and if an objective of the proper kind (4 mm. or higher) was used with a 20× or 30× ocular, the distance between these two surfaces could be measured readily by means of the fine adjustment.

Six such cells were prepared and sent to the committee members. The results of the measurements were as follows:

TABLE I.—LABORATORY MEASUREMENTS OF APPARENT DEPTH, IN MICRONS.[a]

	LABORATORY						
CELL	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
A	3.2	3.2	4.0	3.1	3.2	3.3	3.4
B	4.2	4.1	5.0	4.3	4.0	3.9	4.1
C	3.6	3.7	4.0	3.5	3.7	3.8	3.7
D	7.4	7.5	7.0	7.3	7.3	7.0	8.1
E	13.0	12.8	14.0	[b]	[b]	[b]	[b]
F	8.0	9.2	8.0	8.0	8.0	7.4	8.0

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[a] Measurements corrected to same immersion medium.
[b] Cell E was broken in transit.

These measurements showed a satisfactory agreement between different observers in different laboratories and appeared to confirm, beyond any reasonable doubt, the fact that any two experienced observers can closely check on the measurement of cell depth by using the fine adjustment on a microscope in good working condition.

Cleaning of Quartz Cell:

In the proposed method, Section 5 (*a*), a method for cleaning the quartz cell has been given. This is one point on which the members of the committee are at considerable variance and the methods used and developed by the committee as satisfactory do not correspond to those recommended by the manufacturers.

A rather considerable amount of discussion has been carried on with Mr. W. G. Marquette of The Zeiss Co. and an effort is now being made to prepare a cell having surfaces which are more nearly free from any scratches or imperfections. This work is being carried out in Germany and the results of this investigation are not available at the time of the preparation of this report.

The committee has agreed that with the development of the method an effort should be made to contact all manufacturers of optical equipment and present the problem of preparing a more suitable cell, having the dimensions desired, and to develop methods of cleaning which are more satisfactory and can be more generally applied than those now in use. As a substitute procedure for the one given in the proposed method, the following procedure has been found in one laboratory to give fairly satisfactory results:

> Immerse the cell and cover glass in ether for a few minutes, and then remove them and scrub each thoroughly with liquid soap. This may be accomplished by placing the piece being washed in a suitable cavity in a slab of rubber and rubbing for 5 to 10 min. with the tip of the finger. After scrubbing, rinse the cell and cover glass in distilled water and place in acetic acid for at least 5 min. Then dry them by dipping each in ethyl alcohol followed by ether and wiping with lens paper.

Measurements of Average Particle Diameter:

The next work of the committee consisted of the actual measurement of several common pigments by the proposed method.

Master batches, properly diluted with rubber, and ready for cement making were sent to the committee members with directions for the proportions to be used in cement making and for dilution of the cement with Nujol mineral oil. These quantities and directions were as follows:

PIGMENT	RATIO, PIGMENT TO RUBBER	WEIGHT OF MIX, G.	XYLENE, ML.	AMOUNTS OF CEMENT AND OIL	
				CEMENT, G.	NUJOL MINERAL OIL, G.
P-33 carbon black	30:70	1	100	0.45	40
Zinc oxide[1]	50:50	1	100	0.85	40
Channel black	15:85	1	100	0.35	40

The committee members reported on the average particle diameter of these pigments as shown in Table II. The average of these results and the greatest deviation are also shown in Table II.

The committee frankly states that the results are neither in as good agreement as it believes they should be nor as it is probably possible to obtain.

The primary reason for any lack of agreement in such results lies in the observation of the smallest particles. Particles smaller than 0.2 micron are difficult to see and the pigments on which results have been reported contain a large number of extremely small particles, probably as small as 0.03 micron at least. Results of measuring the average particle size of such materials will vary, depending on the number of the smallest particles seen and counted by a given observer under given conditions.

In cooperative work such as here reported, where the optical apparatus and pigments are the same, the important factors in obtaining discordant results are as follows:

1. Possible agglomeration of the pigment.
2. Unequal distribution in the diluted cement.

TABLE II.—LABORATORY MEASUREMENTS OF AVERAGE PARTICLE DIAMETERS OF PIGMENTS, IN MICRONS.

	LABORATORY					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
P-33 carbon black	0.155	0.173	0.145	0.184	0.170	0.106
Zinc oxide[1]	0.116	.....	0.155	0.143	0.177	.....
Channel black	0.059	.....	0.094	0.086	0.079	0.062

	AVERAGE, MICRON	GREATEST DEVIATION FROM AVERAGE, MICRON	GREATEST DEVIATION, PER CENT
P-33 carbon black	0.165	0.019	12
Zinc oxide[1]	0.148	0.032	22
Channel black	0.076	0.018	24

3. Different brilliancy of the particles which results in a different count of the smallest particles and which is dependent on:
   - (*a*) the intrinsic intensity of the light source;
   - (*b*) the centering of the light and condenser; and
   - (*c*) retinal sensitivity of the observer.

On the basis of certain information which the committee has, it is believed that factors 1 and 2 above are of least importance in the present work, although the committee intends to check these possibilities carefully by further work.

Factor 3 can be and probably is very important. It has been found for example, with P-33 carbon black, that by making counts with an arc lamp and with a ribbon filament lamp, where the difference in intensity is of the order of 10 to 1, the average count is twice as large with the arc lamp.

That the difference in values is the result of counting the smallest particles is indicated by the committee's results on two pigments which contain fewer of the extremely small particles than do the three pigments on which results have been given above. It should be noted that these results were not included in Table II because both pigments contain particles larger than 2 microns.

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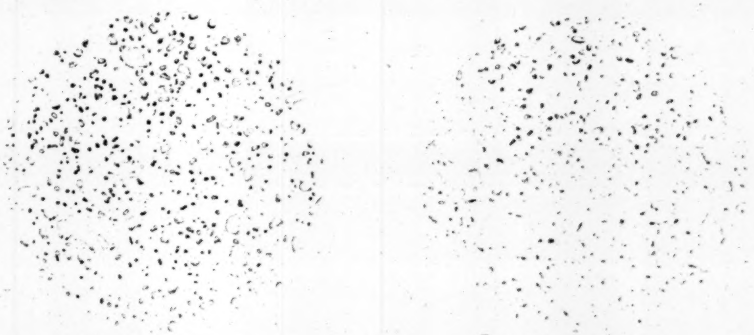
[1] The zinc oxide conformed to the Standard Specifications for Zinc Oxide (A.S.T.M. Designation: D 79), see 1933 Book of A.S.T.M. Standards, Part II, p. 538.

TABLE III.—LABORATORY MEASUREMENTS OF PARTICLE DIAMETERS OF PIGMENTS, IN MICRONS.

PIGMENTS	LABORATORY No. 1	No. 2	No. 3	No. 4	No. 5
Calcene	.....	0.198	0.168	0.193	0.169
Blanc fixe	0.163	0.206	0.218	0.212	0.218

The results on these pigments are in much closer agreement (except for laboratory No. 1 on blanc fixe) than the results on the finer pigments of Table II.



Pigment No. 1. Pigment No. 2.

FIG. 1.—Photomicrographs of Pigment Nos. 1 and 2 (× 1285).

Discussion of Method and Further Studies:

It is clear from this discussion that further work must be done by the committee to find out exactly the magnitude of all possible sources of error. While the results here reported are not entirely unsatisfactory, neither are they entirely successful. In a subsequent report it is hoped that all of these difficulties may be recognized more exactly so that the accuracy of the proposed method may be improved.

The committee desires to call attention to the fact that considerable care should be exercised in the application and interpretation of any data accumulated by this method. The following example is a special contribution of one member[1] of the committee:

As pointed out in the description of the proposed method, appended hereto, the average diameter measured by this procedure represents that average which is a function of the number of particles per gram of pigment. As an example of the difficulty which may be encountered in the interpretation of the results, the pigments Nos. 1 and 2 illustrated in Fig. 1 are cited. Considerable work has been done to explain differences in physical properties noted when these two pigments are incorporated in rubber. A detailed discussion of the physical properties is unnecessary, let it suffice to say that stress-strain properties, abrasion and tear resistance, flexing

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[1] Mr. G. S. Haslam, New Jersey Zinc Co.

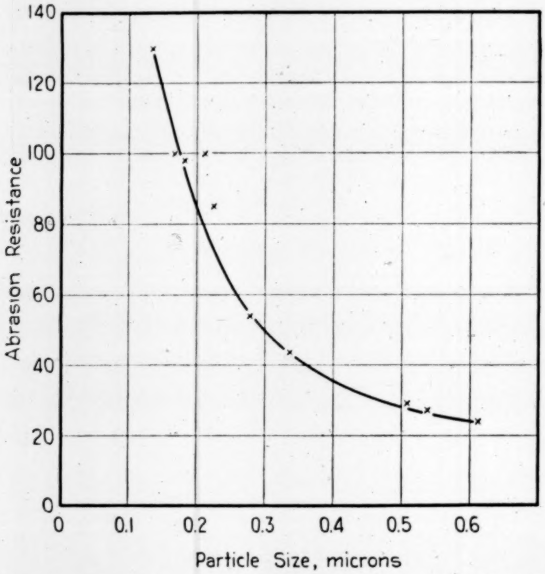

FIG. 2.—Particle Size *versus* Abrasion Resistance for Zinc Oxide.

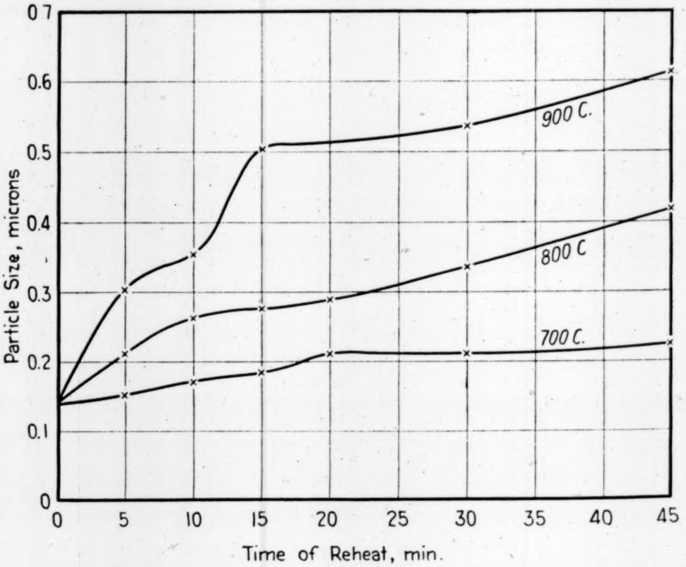

FIG. 3.—Showing the Effect of Reheating Kadox Zinc Oxide at Several Temperatures for Varying Lengths of Time.

life and Banbury dispersion are not the same in each case and that pigment No. 1 is superior in some respects and pigment No. 2 in others.

In an effort to explain these differences, tests have been carried out on the Stutz-Pfund turbidimeter. Pigment No. 1 requires a lower concentration of pigment than pigment No. 2 to give the same opacity. Pigment No. 2, however, shows a greater light scattering power in suspension, indicating the presence of a greater proportion of fines. The use of the centrifuge confirms this conclusion in that a greater amount of colloidal zinc oxide remains in suspension with pigment No. 2 after a given period of centrifuging. Examination of the two photomicrographs permit the conclusion that pigment No. 2 contains both coarser and finer particles than pigment No. 1. In the face of these several tests, it is obvious that there is a difference between the two pigments in question, and that the differences are capable of causing differences in physical properties of rubber compounded with them. The count method under discussion shows the average particle size of these pigments to be essentially the same, namely, 0.283 micron for pigment No. 1 and 0.274 micron for pigment No. 2.

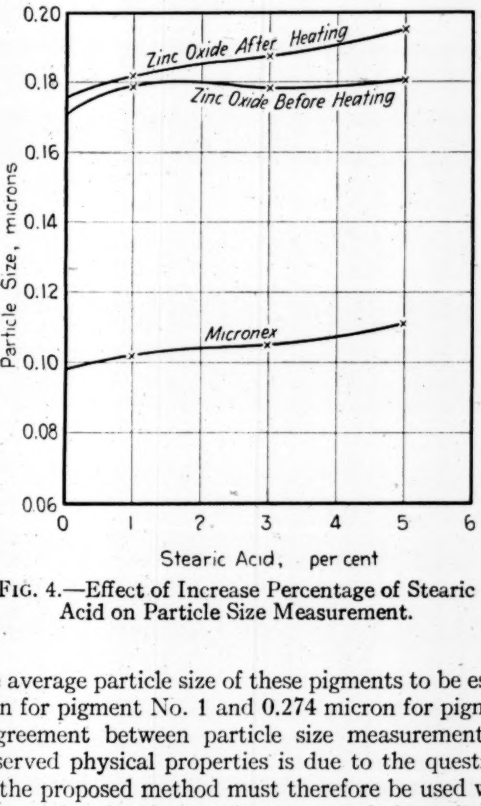

FIG. 4.—Effect of Increase Percentage of Stearic Acid on Particle Size Measurement.

The lack of agreement between particle size measurement by the proposed method and the observed physical properties is due to the question of distribution. Values obtained by the proposed method must therefore be used with this consideration in mind. The two pigments in question were made by quite different processes under different operating conditions, and the variation in distribution is much greater than would be accounted for in any given process under similar operating conditions.

As an illustration of the circumstances under which the test has real significance, a chart showing the relationship between abrasion resistance and particle size, as determined by this method, is shown in Fig. 2. The pigments were all made under similar conditions and a very satisfactory relationship between physical properties and particle size obtained. This is further illustrated in Fig. 3, which shows the relations between time and temperature of calcination of zinc oxide and the resulting particle size.

The committee has given considerable thought to the restrictions which must be placed on the application of this proposed method with the facts in mind of such examples as the one just described. For the present the scope of the proposed method has been limited to material wherein all of the particles are 2 microns or less in diameter. If upon further consideration it appears desirable to modify this limitation, such changes will be considered and any recommendations that appear to be warranted made in subsequent reports.

In an effort to determine the effect of a varying fatty acid content of the rubber, the experiments shown in Fig. 4 were carried out. Stearic acid was added to the pigment-rubber mix in amounts up to 5 per cent on the weight of the rubber. In the case of zinc oxide, little or no change was noted if the rubber-pigment mix was held at relatively low temperatures. If, however, the mix was held at 70 C. for several hours, an increase in particle size was obtained due to the fact that the finer particles of zinc oxide went into solution and were no longer counted.

An increase in particle size with increasing amounts of stearic acid was noted in the case of a channel gas black. In this case, the more logical explanation would be that increasing the stearic acid would cause a poorer dispersion of the black, an observation which has been made in literature by several workers.

The method would lend itself, therefore, to fundamental studies such as these briefly discussed investigations.

Respectfully submitted,

R. P. ALLEN,
G. S. HASLAM,
Co-chairmen.

APPENDIX

PROPOSED METHOD OF MEASUREMENT OF AVERAGE PARTICLE DIAMETER OF SUB-SIEVE PARTICULATE SUBSTANCES BY DARK FIELD METHODS[1]

This is a **proposed draft** and is published as information only. Comments are solicited and should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

1. *Scope.*—(*a*) This method of test is intended for determining the particle size, subsequently defined, of particulate substances in absolute units, in so far as the particle shape will permit. The specific gravities of the materials must be known.

(*b*) The method applies in its entirety to homogeneous materials having a particle size range hereinafter specified. Heterogeneous materials may be measured only if specific gravities of the several components are equal, or nearly so, and have the particle size range specified (Note).

NOTE.—As an example, a lithopone, which is chemically heterogeneous, both components being of nearly the same gravity, having a particle size range of about 0.2 to 1.5 microns may be measured by this method. On the other hand, a calcium-sulfate base pigment containing titanium oxide or zinc sulfide cannot be measured because of the difference in gravity of the two components, although the particle size range may be satisfactory.

(*c*) The method applies primarily to materials wherein all of the particles are 2 microns or less in diameter.

(*d*) With materials having a maximum particle diameter of 2 microns, no restriction is (for the present) placed on shape.

2. *Definitions.*—(*a*) *Dispersion*, in microscopy, refers to the completeness of separation of the individual particles in the dispersing or mounting medium.

(*b*) *Individual Particle* refers to those minute units of matter (of which the material is composed) whose size and shape depend only on the forces of cohesion. Such particle cannot be subdivided without separating like molecules that are within the range of the cohesive attraction of one another.

(*c*) *Ultimate Working Unit* may be an individual particle or it may be any group of individual particles that are so firmly held together by forces of adhesion that they remain intact as a group throughout the duration of their application.

(*d*) *Aggregate* is any group of two or more attached particles. There are three forms of aggregates, namely, ultimate working unit, flocculate, and apparent flocculate.

NOTE.—Flocculation occurs only where particles have been incorporated in a liquid or plastic medium. A *flocculate* is a group of particles held together by a force apparently arising from interfacial tension. This force of flocculation is relatively weak, consequently flocculates do not function as large individual particles, and cannot be classified under *ultimate working units.* Under slight continuously applied force flocculates are constantly breaking down and reforming. *Apparent flocculates* as found in gas-floated or air-floated particles show a somewhat similar type of aggregation. Usually the force of attraction between the particles is relatively weak and the particles can readily be dispersed in suitable media. For practical purposes, the more inclusive term, aggregate, is preferable to flocculate for gas-floated or air-floated particles.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

(*e*) *Average Diameter* is the diameter of a hypothetical particle which, in some particular way, represents the total mass of particles.

(*f*) *Non-uniformity* or a non-uniform particulate substance is one in which the constituent particles differ from one another in diameters.

3. *Average Particle Diameter.*—The average particle diameter is based on the number of particles per gram and is, therefore, a function of the average volume of the particle; that is, the average diameter used in this method is the diameter of a hypothetical sphere such that the volume of n such spheres is equal to the actual volume of n particles.[1] Mathematically expressed it is:

$$\sqrt[3]{\frac{\Sigma\, nd^3}{\Sigma\, n}}$$

4. *Preparation of the Mount.*—(*a*) The pigment of which the average particle diameter is to be measured shall be milled into clean pale crepe rubber in a suitable concentration which varies usually from 30 to 60 per cent depending on the size and specific gravity of the pigment. The batch shall be remilled on a cold mill and then examined microscopically. The method of Allen[2] is a convenient one for preparing sections for this examination. The examination is made for the purpose of determining the excellence of dispersion and to observe the range of sizes and the maximum size of particle. Remilling shall be continued or repeated until the dispersion is perfect. Suitable softening or dispersing agents may be used if desired.

(*b*) The master batch shall be diluted with clean pale crepe rubber and milled until it will dissolve in xylene to give a smooth, completely soluble cement. This dilution with pale crepe will vary from about 1 part of master batch to 4 parts of rubber to 1 part of master batch to 2 parts of rubber.

(*c*) In making up the xylene cement, the aim should be to obtain a pigment concentration of about 1 to 5 per cent. The weighing of the master batch shall be made on an analytical balance to the nearest 0.01 g.

(*d*) The xylene cement shall be diluted with Nujol or equivalent mineral oil, one or two drops of the cement being added to a suitable amount of the oil. The weighing shall be carried out on an analytical balance. A small glass-stoppered Erlenmeyer flask is satisfactory in which to perform the weighing. Vigorous shaking with some standing will result in complete dispersion of the pigment. The final concentration shall be such that about 20 to 30 particles will appear in the field.

5. *Counting of the Particles.*—(*a*) The quartz chamber[3] must be first scrupulously cleaned. The cell and the cover glass shall be heated for several minutes in a dichromate cleaning solution, rinsed twice in hot distilled water and dried over a hot plate after immersion in absolute alcohol.

(*b*) The cell shall be placed in the chamber holder, a small drop of the oil suspension added, the quartz cover glass then placed in position and the chamber holder screwed down.

(*c*) The microscope in which the cell is to be observed shall be equipped with a cardoid condenser, a 3-mm. glycerol immersion objective, a 20× or 30× ocular in which is placed either an Ehrlich stop or a suitable ocular micrometer marked off in squares, and an arc lamp should be used for illumination.

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[1] For a more complete discussion see the Tentative Method of Analysis for the Particle Size and Distribution of Sub-Sieve Size Particulate Substances (A.S.T.M. Designation: E 20 – 33 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 989 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1399.

[2] Allen, "Method of Making Micro-Sections of Rubber Stocks," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 2, p. 311 (1930).

[3] Zeiss, Leitz, or Bausch & Lomb chambers are suitable.

(*d*) The cell depth shall be measured by means of the graduated fine adjustment of the microscope. The instrument shall be first focussed on the under side of the cover slip and the fine adjustment reading noted; the tube shall be then lowered slowly to the point where the lowest particles in the cell, that is, the bottom surface of the cell, are in focus and the fine adjustment reading noted. The difference in the two readings multiplied by the proper factor (which will be given on the fine adjustment arm) gives the apparent cell depth. Two such readings shall also be obtained by focussing up from bottom to top. In every case the tube shall be moved only in one direction when making readings, to eliminate any possible error caused by back-play. The apparent depth shall be thus measured twice in each direction and the results averaged.

(*e*) The value of the apparent depth having been obtained, the true depth of the cell is found by the following formula:

$$T = \frac{N_u \times t}{N_i}$$

where T = the corrected depth in microns
t = the measured movement of the tube in microns
N_u = the refractive index of the dispersion medium
N_i = the refractive index of the immersion medium between the cover glass and the front lens of the objectives

NOTE.—In the method as here given using a glycerol immersion objective and with a Nujol or equivalent oil suspension, this corrective factor is practically 1.

(*f*) The number of particles in a selected volume defined by the Ehrlich stop or ruled area of the ocular micrometer and the depth of the cell, shall be counted by slowly focussing up or down from top to bottom of the cell. Care should be observed to accommodate the eyes before starting the count, so that the faintest particles may be seen. A hand counter will be found helpful in recording the number of particles. Enough fields selected at random shall be counted to guarantee a true average. This may vary from 10 to 50, depending on the uniformity of the pigment under consideration.

6. *Calculation of Results.*—The value for the average particle diameter is obtained from the foregoing data by use of the following formula:

$$D = 10^{-4}\sqrt[3]{\frac{6\,CV}{\pi \rho n}}$$

where D = the average diameter in microns
C = the concentration of pigment, in grams per cubic centimeter
ρ = the density of the pigment
n = the average of at least 10 fields, in particles per field
V = the volume of the field counted, in cubic centimeters

REPORT OF COMMITTEE E-2

ON

SPECTROGRAPHIC ANALYSIS

Committee E-2 on Spectrographic Analysis held only one meeting during the year, at the annual meeting of the Society at Atlantic City, N. J., on June 26, 1934. No definite action was taken at that time with regard to standards, and the work of the committee during the year has been confined to the activities of subcommittees, which are briefly summarized in this report.

It is with regret that the committee records the death in October, 1934, of Mr. L. G. Morell, of the Dow Chemical Co., whose long and varied experience and whose enthusiastic willingness to cooperate had promised valuable aid in the work of the committee.

Five new members have been elected during the year, one member has been lost by resignation and the one member lost by death leave a net increase of three in the membership of the committee which now totals 37.

Subcommittee II on Fundamental Methods and Technique (O. S. Duffendack, chairman).—This subcommittee held one meeting during the year in connection with the spectroscopy conference at the Massachusetts Institute of Technology on July 17, 1934. Consideration was given to the project assigned to the subcommittee at the annual meeting, which was the preparation of a report critically discussing and comparing the various procedures in quantitative analysis that have been proposed, and that are in use in various laboratories with the aim of determining the best methods of general procedure to serve as a basis for the selection of methods later to be recommended by the committee as Society standards. It was felt by many of those present that definite conclusions as to the best methods of procedure could only be reached after a rather extensive program of research, preferably in the universities represented on the committee. The question of whether such a program could be sponsored by the Society and, perhaps, financed by contributions from the laboratories which might be expected to benefit from the results attained, was referred to the chairman of Committee E-2 and the Secretary-Treasurer of the A.S.T.M. Through later correspondence it was decided that it would be inadvisable at this time for the committee to undertake a project of this kind in the way suggested.

This subcommittee has also distributed a questionnaire to the members of Committee E-2 in an attempt to learn the essential details of procedure used in the various laboratories, the accuracy and precision of the results obtainable by the various methods, and other details that will aid them in their study of the whole situation. The results of this work will be reported.

Subcommittee III on Quantitative Methods and Applications (M. L. Fuller, chairman).—This subcommittee has been very active during the year and as a result has formulated preliminary drafts of three proposed methods of spectrochemical analysis, as follows:

Method of Test for Quantitative Spectrochemical Analysis of High Grade Pig Lead for Copper, Bismuth, Silver, and Nickel.

Method of Test for Quantitative Spectrochemical Analysis of Zinc for Lead, Iron, and Cadmium.

Method of Test for Quantitative Spectrochemical Analysis of Zinc Alloy Die-Castings for Minor Constituents and Impurities.

The first is used for the analysis of high grade pig lead for certain impurities that are limited by specifications. (See the Tentative Specifications for Pig Lead (B 29 – 34 T).)

The second, which is used for the examination of zinc for the more commonly occurring impurities, may be applied to any grade of zinc, provided the lead, iron, and cadmium contents are less than 0.1 per cent.

The third is to be used for the analysis of zinc-base die castings and die-casting alloys to insure that the minor constituents are between the high and low limits and that deleterious impurities are less than the maximum limits permitted by the A.S.T.M. Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 – 34 T).

These several methods will be brought up for discussion at the Detroit meeting in the hope that they may be considered suitable for submission to the Society for publication as tentative methods.[1] They are based on the experience of laboratories which have used them for a period of several years and have found them reliable.

Subcommittee V on Standards and Pure Materials (T. A. Wright, chairman).—This subcommittee has also been active in gathering information with regard to available sources, both of pure metals as free as possible from contaminating elements and of commercial grades of metals which have been analyzed with care so that they may be used as standard samples on which to base the quantitative spectrographic methods. No formal report of this subcommittee is ready for presentation but the chairman expects to have considerable valuable information ready to report at the Detroit meeting.

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[1] Subsequent to the annual meeting Committee E-2 presented to the Society through Committee E-10 on Standards the three proposed Tentative Methods of Quantitative Spectrochemical Analysis, which were accepted for publication as tentative and appear respectively on pp. 1352, 1357 and 1362.—ED.

The committee has arranged as a feature of the annual meeting in Detroit a Symposium on Spectrographic Analysis to be held on Friday morning, June 28. The program has been arranged with two objects in view, one to give those who are working in this field definite information as to the methods used by those who are depending upon spectrographic analysis for the control of quality in a variety of industries; the other to indicate to those not actually engaged in spectrographic work, but interested in the possibility of securing more rapid and reliable methods of testing, the fact that numerous laboratories have found in the spectrograph an invaluable tool that will shorten the time required for analyses and give more complete and definite information as to the composition of materials than can be obtained in any other way. The symposium will comprise the following papers describing methods and details of procedure which have been found applicable to the analysis of various metals:

"Spectrographic Analysis of Steel Samples," by W. R. Brode, Ohio State University.
"The Use of the Spectrograph in the Platinum Industry," by H. E. Stauss, Baker and Co., Inc.
"Quantitative Spectrographic Analysis of Magnesium Alloys for Manganese and Silicon," by J. S. Owens and T. M. Hess, The Dow Chemical Co.
"The Spectrographic Determination of Impurities in Commercial Cadmium," by Frances W. Lamb, Bohn Aluminum and Brass Corp.
"The Purification of Graphite Electrodes for Spectrochemical Use," by G. W. Standen and L. Kovach, Jr., The New Jersey Zinc Co.
"Quantitative Analysis of Non-Ferrous Alloys by Spectroscopic Methods," by R. A. Wolfe, University of Michigan.

It is hoped through this symposium to create a wider interest and confidence in spectrographic methods for the enforcement of the Society's specifications.

This report has been submitted to letter ballot of the committee which consists of 37 members; 25 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. V. CHURCHILL,
Chairman.

C. C. NITCHIE,
Secretary.

REPORT OF COMMITTEE E-4
ON
METALLOGRAPHY

During the year, Committee E-4 on Metallography held one meeting in Atlantic City, N. J., on June 26, 1934. A meeting of Subcommittee I was held in Philadelphia, Pa., on March 7, 1935, and a meeting of Subcommittee VI in New York City, on October 2, 1934.

During the year, there has been correspondence concerning the work of the proposed subcommittee on the structure of tool steels and definite progress is being made looking toward undertaking work on this subject.

Committee E-4 is sponsoring an exhibit of micrographs and photographs in connection with the Exhibit of Testing Apparatus and Related Equipment being held by the Society at the Book-Cadillac Hotel in June, at Detroit, Mich., during the annual meeting of the Society. The display will include micrographs, macrographs, as well as pictures made by various types of X-ray equipment. The display will be in charge of Mr. C. J. Tobin, and its success is already assured by the widespread interest among the membership of Committee E-4.

The committee has reviewed the standards under its jurisdiction and is considering submitting the following to the American Standards Association for approval as American Standards under the proprietary sponsorship method:

Recommended Practice for Thermal Analysis of Steel (E 14 – 33)

Subcommittee I on Selection and Preparation of Samples (E. H. Dix, Jr., chairman).—Subcommittee I has prepared an extensive revision of the Standard Methods of Metallographic Testing of Iron and Steel (E 3 – 24) and the Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 27). These two standards have been combined into a proposed Recommended Practice for Metallographic Testing of Ferrous and Non-Ferrous Metals, appended hereto,[1] which is being recommended for publication as tentative. Mr. Dix and his assistants deserve much praise for their worthy and painstaking endeavors in completing this comprehensive compilation of metallographic procedures.

Subcommittee IV on Photography (Leon Foster, chairman).—This subcommittee is engaged in a further study of the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (E 2 – 30). It is expected that this will result in certain changes being proposed in this standard for publication as tentative.

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[1] See p. 1319.—Ed.

Subcommittee VI on X-ray Methods (R. F. Mehl, chairman).—Subcommittee VI has been particularly active this year. A meeting was held in New York City, on October 2, 1934, at which a proposed A.S.T.M. X-ray Symposium was discussed. As a result of this meeting and after securing approval from the Society, it was decided to proceed in accordance with the following general plan:

1. A preliminary symposium will be held at the June meeting in Detroit this year. This will not be open to the general membership of the Society. Its object will be to review the material which will have been assembled.

2. A formal symposium will be held at the meeting of the Society in June, 1936. This will consist of a series of carefully organized papers, and will ultimately appear as a Society publication.

The object of these symposiums will be to present summary accounts of the present status of X-ray methods in the testing of materials in order that the real usefulness of such methods may be evaluated. The following items are an elaboration of this general statement:

(*a*) To describe modern methods and equipment in an elementary way in order to assist industries in the application of X-rays to their work.

(*b*) To present as many case histories of successful applications as possible.

(*c*) To compare the usefulness of X-ray methods with the usefulness of other methods which may be used alternatively.

(*d*) To include the application of radiographic and diffraction methods to both metallics and non-metallics.

RECOMMENDATIONS AFFECTING STANDARDS

The proposed Tentative Recommended Practice for Metallographic Testing of Ferrous and Non-Ferrous Metals, appended hereto,[1] is recommended for publication as tentative to supersede when adopted as standard the existing Standard Methods of Metallographic Testing of Iron and Steel (E 3 – 24) and the Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 27).

This recommendation has been submitted to letter ballot of the committee, which consists of 49 members; 39 members returned their ballots, all of whom have voted affirmatively.

This report has been submitted to letter ballot of the committee which consists of 49 members; 39 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

C. H. DAVIS,
Chairman

O. E. HARDER,
Secretary.

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[1] See p. 1319.—ED.

REPORT OF COMMITTEE E-9
ON
RESEARCH

With this report is presented a brief summary of some of the research projects being carried on under the auspices of the Society. A much more comprehensive review will be published as a supplement to the October, 1935, issue of the Society *Bulletin*.

Research Committee Activities:

The Research Committee on Yield Point of Structural Steel has for another year been forced to mark time owing to the difficulty in finding means for carrying on its program of laboratory work. The committee is meeting during this annual meeting of the Society and it is hoped that the way may be made clear for the completion of the investigative program of the committee. The general subject of elastic strength of metals and the significance of such properties as elastic limit, proportional limit, yield strength and yield point, is assuming increasing importance and its importance has been recognized by arrangements made by the Committee on Papers and Publications for a discussion at this annual meeting on "The Significance of Yield Strength of Metals in Design and Specifications."

The Research Committee on Fatigue of Metals is reporting[1] currently to the Society at this annual meeting. It has continued its cooperation with *Metals and Alloys* in the preparation of abstracts of articles dealing with fatigue of metals and in planning and preparing critical abstracts on the subject. The committee further is cooperating with Committee E-4 on Metallography on the use of X-ray methods as a means of detecting impending fatigue failure. A progress report on this cooperative work is included in the annual report of the research committee. Finally, the committee has prepared what promises to be a very useful report entitled "Notes on Fatigue Tests on Rotating-Beam Testing Machines."[2] These notes are in the nature of recommended practices rather than standard methods of testing, although the development of such methods may conceivably grow from this preliminary statement of the subject.

The Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel completed a year ago the projects that were actively before it and has undertaken no new work during the year. It is hoped that when commercial conditions improve the projected study of effect of phosphorus in steel castings may be undertaken.

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[1] See p. 111.—Ed.
[2] See p. 113.—Ed.

The Joint Research Committee of the A.S.M.E. and A.S.T.M. on Effect of Temperature on the Properties of Metals has prepared a comprehensive report[1] of its activities for the year, which is being presented to the Society at this annual meeting. Investigations sponsored by the committee at Battelle Memorial Institute have been continued during the year, as outlined in the committee's report. One phase of the study, dealing with embrittlement of austenitic nickel-chromium steels as a result of prolonged exposure to high temperatures, has been completed and a summary of the findings published with the committee's report. The Joint Committee has reviewed during the year the Tentative Methods of Test for Short-Time (E 21 – 34 T) and Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 – 34 T) written by the committee, accepted as tentative in 1933 on the recommendation of the Joint Committee and revised last year. The committee this year is proposing a number of changes and additions that seem desirable in the second of these two methods.[2] As an aid to the user of this method the committee has prepared a brief description of the generally recognized practices in matters dealing with evaluation or interpretation of creep test data.

Research Projects by Standing Committees:

One of the functions of Committee E-9 is to review annually the progress of the Society's research activities. These activities have been steadily growing, numbering last fall something over 100. A brief statement of the status of each of those projects was published in a supplement to the October, 1934, *Bulletin*. Project cards for each of these research activities are maintained in the office of the Secretary-Treasurer and are brought up to date annually by review of the reports of the standing committees. It is planned to publish a revised and up-to-date review of the current research projects as a supplement to the October, 1935, *Bulletin*. Members of the Society should refer to that review for a comprehensive picture of the nature of and progress being made in these numerous researches.

New Activities:

Committee E-9 has been seeking to promote further interest in two matters that it believes to be of importance. The first of these is a critical and extended study of the effect of speed of loading in determining the properties of masonry materials. As the outcome of a conference held last December under the auspices of the committee it is hoped that ways and means can be found for the institution of a study of this matter under the sponsorship of the committee in cooperation with the Section on Effect of Speed of Testing functioning under Committee E-1 on Methods of Testing. The committee is prepared to contribute from the Research Fund of the Society in support of a study of the subject that gives promise of providing the desired information.

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[1] See p. 121.—ED.

[2] The revised method appears on p. 1291.—ED.

The second matter has to do with the durability of masonry materials and especially the importance of fundamental studies to determine what takes place in these materials when subjected to the commonly-used accelerated weathering tests. This subject likewise was discussed at a conference held last December under the auspices of the committee, which included members of the Society's Coordinating Committee on Weathering Characteristics of Masonry Materials and representatives from interested standing committees, and it seemed clear that such studies would be needed before it would be possible to unify the present test methods for accelerated weathering and correlate laboratory with field results.

At the present time durability is predicted upon the basis of strength, usually compressive, porosity (or total absorption), rate of absorption, and disintegration following cycles of freezing and thawing of water or crystallization and solution of salts. Very many data are available on some of these items and less on others. Thus, many compressive strength results and total absorption values are at hand. Fewer data are available regarding tensile strength and rate of absorption. The data secured from freezing-and-thawing tests are difficult of interpretation and correlation, due to the lack of uniformity in test procedure.

It would seem needful, therefore, to study rather critically, in some cases, certain of the test procedures to determine if possible what method should be followed to duplicate field results as nearly as possible. This applies especially to freezing-and-thawing (crystallization and solution) test methods. In the case of tensile strength and rate of absorption many more data are needed.

The conference outlined three investigations that it believes can be most advantageously carried out: rates of absorption, tension tests and freezing-and-thawing tests. Of these the last is especially needed and must be done before such tests can be placed upon a proper basis. It is believed that there are one or more well-equipped institutions which, with an accessory fund of about $2500 per annum, could make considerable headway in obtaining these data, and other institutions which would require somewhat heavier subsidies. It would seem that to carry out the work properly and effectively some financial assistance might be made by interested industries or groups having charge of funds for aiding research if the matter were brought to their attention.

Miscellaneous Administrative Matters:

The term of H. C. Mougey expired in June, 1934, and R. W. Crum was appointed to membership in his place.

The term of H. F. Moore expires at the close of this annual meeting; appointment of his successor will be made by the Executive Committee. In noting the termination of Professor Moore's membership, the committee wishes to call attention to the outstanding services that he has rendered to the committee and to the Society in the work of this committee. He has been a member of the committee continuously during the eleven years since the committee was organized in 1924 and he served as chairman of the committee for ten years. Such a record of useful service in the interest of the Society's research activities should not go unnoticed and the committee is glad to record its appreciation of these years of service as member and chairman.

The principal of the A.S.T.M. Research Fund is $8179.35. The balance of income as of May 31, 1935, is $1712.28.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

C. L. WARWICK,
Secretary.

June, 1935.

REPORT OF COMMITTEE E-10
ON
STANDARDS

The activities of Committee E-10 on Standards during the past year are set forth under the following heads: Review of A.S.T.M. standardization activities, consideration of new and revised standards and tentative standards, promotion and expansion of standardization activities, and relations with American Standards Association.

As will be noted, a very considerable number of new tentative standards and revisions of existing standards and tentative standards have been submitted to Committee E-10 during the year for approval. For the most part these were considered at the regular meeting of the committee held in Philadelphia, Pa., on August 22, 1934, although a number of the standards were handled by correspondence in instances where a very clear case had been submitted by the standing committees concerned. In addition to this regular meeting a special meeting was held on May 6, 1935, in conjunction with the Standardization Committee of the American Railway Engineering Association. This latter meeting proved to be a most interesting one at which various problems relating to standardization, of mutual interest to the two societies, were discussed. These discussions should lead to even greater cooperation between the two societies than existed in the past.

In the 1934 report[1] of Committee E-10, mention was made of the possibility of publishing draft standards as information in the A.S.T.M. *Bulletin*. Since the authorization of this method of publication, one committee of the Society has availed itself of this type of publication, namely, Committee B-2 on Non-Ferrous Metals and Alloys, on whose recommendation proposed Specifications for Lead-Coated Copper Sheets were published in the January issue of the A.S.T.M. *Bulletin*.

Beginning with the annual meeting of the Society in June, 1934, the personnel of the committee was placed on a rotational basis and under this plan Mr. J. O. Leech of the Carnegie Steel Co. and Mr. J. B. Young of the Reading Co. were appointed to serve as members of the committee for a three-year term.

REVIEW OF A.S.T.M. STANDARDIZATION ACTIVITIES

A general summary of the new tentative standards submitted at the 1934 annual meeting, of tentative standards advanced to standard and of revisions in standards was included in the July issue of the A.S.T.M. *Bulletin*, together with a review of the standardization work of the various committees with statements concerning new standards in prospect. Much of the information, particularly in respect to standardization projects in development in committees, is furnished by the standing committees subsequent to the annual meeting and takes advantage of the fact that many committees plan their next year's work at committee meetings held during the annual meeting.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 582 (1934).

At the present writing, it is possible to make only an approximate estimate in terms of new and revised standards of the volume of standardization work accomplished during the year and reported to the Society at this meeting. The reports of standing committees to be presented at the annual meeting include recommendations to the Society substantially as follows:

New tentative standards	45
Tentative revisions of existing standards	28
Revisions of tentative standards	49
Tentative standards recommended for adoption as standard	20
Revisions of existing standards recommended for adoption as standard	17
Standards and tentative standards withdrawn	12

There are at present 491 standards and 241 tentative standards of the Society, making a total of 732, and if the above recommendations are approved this total will become 763.

CONSIDERATION OF NEW AND REVISED STANDARDS

Committee E-10, on receiving recommendations from standing committees on the submission of new tentative standards or revisions of existing tentative standards or standards, reviews them principally to insure that a substantial consensus has been reached in the standing committee concerned. It requires that a complete vote be recorded, analyzed according to producers, consumers, and general interests. If there are any negative votes, the names of those voting in the negative must be recorded together with the reasons for so voting. A report from the standing committee is required giving the usual information, setting forth the needs for having the standard and on what data the standard is based, that is, whether it is based on standards already in existence or on work carried out by the committee, etc.

Proposed new standards approved by Committee E-10 and published as tentative during the year are as follows:

Tentative Specifications for Alloy-Steel Castings for Valves, Flanges and Fittings for Service at Temperatures from 750 to 1100 F. (A 157 - 34 T), submitted by Committee A-1 on Steel

Tentative Specifications for Seamless Alloy-Steel Pipe for Service at Temperatures from 750 to 1100 F. (A 158 - 34 T), submitted by Committee A-1

Tentative Specifications for Pig Lead (B 29 – 34 T), submitted by Committee B-2 on Non-Ferrous Metals and Alloys

Tentative Specifications for Copper-Silicon Alloy Plates and Sheets (B 96 – 34 T), submitted by Committee B-5 on Copper and Copper Alloys, Cast and Wrought

Tentative Specifications for Sheet Copper-Silicon Alloy (B 97 – 34 T), submitted by Committee B-5

Tentative Specifications for Copper-Silicon Alloy Rods, Bars and Shapes (B 98 – 34 T), submitted by Committee B-5

Tentative Methods of Chemical Analysis of Portland Cement (C 114 – 34 T), submitted by Committee C-1 on Cement

Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (C 115 – 34 T), submitted by Committee C-1

Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 – 34 T), submitted by Committee C-8 on Refractories

Tentative Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 – 34 T), submitted by Committee C-8

Tentative Method of Test for Permanent Linear Change After Reheating of Refractory Brick (C 113 – 34 T), submitted by Committee C-8

Tentative Specifications for Structural Clay Load-Bearing Wall Tile (C 34 – 34 T), submitted by Committee C-10 on Hollow Masonry Building Units

Tentative Specifications for Structural Clay Non-Load-Bearing Tile (C 56 – 34 T), submitted by Committee C-10

Tentative Specifications for Structural Clay Floor Tile (C 57 – 34 T), submitted by Committee C-10

Tentative Methods of Sampling and Testing Structural Clay Tile (C 112 – 34 T), submitted by Committee C-10

Tentative Specifications for Fuel Oils (D 396 – 34 T), submitted by Committee D-2 on Petroleum Products and Lubricants

Tentative Specifications for Emulsified Asphalt (For Coarse Aggregate Plant Mixes) (D 397 – 34 T), submitted by Committee D-4 on Road and Paving Materials

Tentative Specifications for Emulsified Asphalt (For Retread and Coarse Aggregate Mixes) (D 398 – 34 T), submitted by Committee D-4

Tentative Specifications for Emulsified Asphalt (Heavy Premix—Summer Grade) (D 399 – 34 T), submitted by Committee D-4

Tentative Specifications for Emulsified Asphalt (Heavy Premix—Winter Grade) (D 400 – 34 T), submitted by Committee D-4

Tentative Specifications for Emulsified Asphalt ((Quick-Setting) for Penetration and Surface Treatment) (D 401 – 34 T), submitted by Committee D-4

Tentative Method of Test for Separation of Liquid Asphaltic Products (D 402 – 34 T), submitted by Committee D-4

Tentative Specifications for Tolerances and Test Methods for Woolen Yarns (D 403 – 34 T), submitted by Committee D-13 on Textile Materials

Tentative Specifications for Tolerances and Test Methods for Worsted Yarns (D 404 – 34 T), submitted by Committee D-13

Tentative Definitions of Terms Consistency and Plasticity (E 24 – 34 T), submitted by Committee E-1 on Methods of Testing

Revisions of the following existing standards and tentative standards were approved by Committee E-10:

Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 34 T), submitted by Committee A-1 on Steel

Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 33), submitted by Committee A-1

Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 33), submitted by Committee A-1

Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33), submitted by Committee A-1

Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 33), submitted by Committee A-1

Standard Specifications for Structural Steel for Ships (A 131 – 33), submitted by Committee A-1

Standard Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (B 60 – 28), submitted by Committee B-5 on Copper and Copper Alloys, Cast and Wrought

Standard Specifications for Steam or Valve Bronze Sand Castings (B 61 – 28), submitted by Committee B-5

Standard Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 – 28), submitted by Committee B-5

Tentative Specifications for Zinc-Base Alloy Die Castings (B 86 – 34 T), submitted by Committee B-6 on Die-Cast Metals and Alloys

Tentative Method of Test for Particle Size of Ground Refractory Materials (C 92 – 34 T), submitted by Committee C-8 on Refractories

Tentative Specifications for Refractories for the Construction of Incinerators (C 106 – 34 T), submitted by Committee C-8

Standard Method of Test for Refractory Materials Under Load at High Temperatures (C 16 – 20), submitted by Committee C-8

Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 – 33), submitted by Committee C-8

Tentative Specifications and Tests for Load-Bearing Concrete Masonry Units (C 90 – 34 T), submitted by Committee C-10 on Hollow Masonry Building Units

Tentative Methods of Testing Emulsified Asphalts (D 244 – 34 T), submitted by Committees D-4 on Road and Paving Materials and D-8 on Bituminous Waterproofing and Roofing Materials

Tentative Specifications for Asphalt Roofing Surfaced with Powdered Talc or Mica (D 224 – 34 T), submitted by Committee D-8

Tentative Specifications for Asphalt Shingles Surfaced with Coarse Mineral Granules (D 225 – 34 T), submitted by Committee D-8

Tentative Specifications for Asphalt Roofing Surfaced with Fine Mineral Granules (D 248 – 34 T), submitted by Committee D-8

Tentative Specifications for Asphalt Roofing Surfaced with Coarse Mineral Granules (D 249 – 34 T), submitted by Committee D-8

Tentative Methods of Testing Untreated Paper Used in Electrical Insulation (D 202 – 34 T), submitted by Committee D-9 on Electrical Insulating Materials

Tentative Methods of Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 34 T), submitted by Committee D-9

Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (D 256 – 34 T), submitted by Committee D-9

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 33), submitted by Committee D-9

Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (D 27 – 34 T), submitted by Committee D-11 on Rubber Products

Tentative Specifications and Tests for Rubber Insulating Tape (D 119 – 34 T), submitted by Committee D-11

Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (D 353 – 34 T), submitted by Committee D-11

Tentative Methods of Test for Abrasion Resistance of Rubber Compounds (D 394 – 34 T), submitted by Committee D-11

Tentative Method of Estimating Hard Scoured Wool in Wool in the Grease (D 232 – 34 T), submitted by Committee D-13 on Textile Materials

Tentative Specifications for Asbestos Roving (D 375 – 34 T), submitted by Committee D-13

Standard Specifications for Asbestos Yarns (D 299 – 33), submitted by Committee D-13

Standard Specifications for Chafer Tire Fabrics (D 316 – 34), submitted by Committee D-13

Tentative Methods of Verification of Testing Machines (E 4 – 34 T), submitted by Committee E-1 on Methods of Testing

Tentative Methods of Impact Testing of Metallic Materials (E 23 – 34 T), submitted by Committee E-1

Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (E 21 – 34 T), submitted by Joint Committee on Effect of Temperature on the Properties of Metals

Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 – 34 T), submitted by Joint Committee on Effect of Temperature on the Properties of Metals

The withdrawal of the following standards was approved by Committee E-10:

Standard Specifications for Pig Lead (B 29 – 23), on the recommendation of Committee B-2 on Non-Ferrous Metals and Alloys

Standard Specifications for the Alloy: Copper 88 per cent; Tin 10 per cent; Zinc 2 per cent (B 10 – 18), on the recommendation of Committee B-5 on Copper and Copper Alloys, Cast and Wrought

Standard Specifications and Tests for Structural Clay Load-Bearing Wall Tile (C 34 – 31), on the recommendation of Committee C-10 on Hollow Masonry Building Units

Standard Specifications and Tests for Structural Clay Fireproofing, Partition and Furring Tile (C 56 – 31), on the recommendation of Committee C-10

Standard Specifications and Tests for Structural Clay Floor Tile (C 57 – 31), on the recommendation of Committee C-10

Standard Definitions of Terms Relating to Structural Clay Tile (C 43 – 31), on the recommendation of Committee C-10

PROMOTION AND EXPANSION OF STANDARDIZATION ACTIVITIES

Of the several subjects referred to in the 1934 report[1] of the committee as having been suggested for development in the Society, the subject of gaseous fuels has reached the point where a standing committee has been authorized and organization is being effected at the present annual meeting. The committee on paper and allied products will probably be organized within the next few months since considerable interest has been expressed in this proposed new activity, particularly on the part of the Society's Committee D-9 on Electrical Insulating Materials, which committee would wish to see some definite means of cooperation established with the Technical Association of the Pulp and Paper Industry. The subject of heat insulating materials is also being developed to determine the extent of interest in this field.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 585 (1934).

While the subject of plastics and synthetic resins has been under discussion for several years no steps have as yet been taken to organize a committee in this field. There is a possibility that a symposium on this subject will be held during the coming year by the New York District Committee and this discussion may point the way to further development of the subject.

Mention was made in last year's report of the committee of the possibility of a committee on soap, with particular reference to its use as a lubricant. Since then the need for standardization of specifications with respect to the use of soap and similar compounds as a detergent has been emphasized and inquiry is being made of various organizations interested to determine whether a committee dealing with detergents should be established.

A number of suggestions from various sources have been referred to existing committees for development, namely, specifications for sheet low brass to Committee B-5 on Copper and Copper Alloys, Cast and Wrought, specifications for plaster bond and the standardization of a test procedure for determining fineness of ground mica to Committee D-8 on Bituminous Waterproofing and Roofing Materials, and the standardization of the penetration fracture test for tool steels to Committee E-4 on Metallography.

RELATIONS WITH AMERICAN STANDARDS ASSOCIATION

Standards Submitted Under Proprietary Sponsorship Procedure.—The proprietary sponsorship procedure for submitting standards to the American Standards Association is particularly appropriate for a large number of A.S.T.M. standards. A number of standing committees now have under consideration the submission of existing A.S.T.M. standards to the A.S.A. under this method. The following standards have been approved during the year by the A.S.A. as American Standards:

Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 33) (A.S.A. No. G17.1 – 1934)

Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 33) (A.S.A. No. G17.2 – 1934)

Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 33) (A.S.A. No. G17.3 – 1934)

Standard Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 – 29) (A.S.A. No. H8 – 1934)

Standard Specifications for Copper Water Tube (B 88 – 33) (A.S.A. No. H23.1 – 1934)

Standard General Methods of Testing Woven Textile Fabrics (D 39 – 34) (A.S.A. No. L5 – 1934)

Standard Submitted Under Sectional Committee Procedure.—Reports have been received from several of the sectional committees for which the Society is sponsor, submitting standards to the A.S.A. for approval. These reports have been transmitted to that association and the following standards have been approved during the year as American Standards:

On the Recommendation of Sectional Committee A2 on Fire Tests of Materials and Construction:

Standard Specifications for Fire Tests of Building Construction and Materials (C 19 – 33) (A.S.A. No. A2 – 1934)

On the Recommendation of Sectional Committee C59 on Electrical Insulating Materials:

Standard Methods of Testing Molded Materials Used for Electrical Insulation (D 48 – 33) (A.S.A. No. C59.1 – 1935)

Standard Methods of Testing Electrical Insulating Oils (D 117 – 33) (A.S.A. No. C59.2 – 1935)

Standard Methods of Test for Resistivity of Insulating Materials (D 257 – 33) (A.S.A. No. C59.3 – 1935)

Standard Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 – 24) (A.S.A. No. C59.4 – 1935)

On the Recommendation of Sectional Committee Z11 on Petroleum Products and Lubricants:

Standard Method of Test for Cloud and Pour Points (D 97 – 34) (A.S.A. No. Z11.5 – 1934)

Standard Method of Test for Sulfur in Petroleum Oils by Bomb Method (D 129 – 34) (A.S.A. No. Z11.13 – 1934)

Standard Abridged Volume Correction Table for Petroleum Oils (D 206 – 34) (A.S.A. No. Z11.1 – 1934)

On the recommendation of Sectional Committee B36 on Standardization of Dimensions and Material of Wrought-Iron and Wrought-Steel Pipe and Tubing, the Standard Specifications for Electric-Resistance-Welded Steel Pipe (A 135 – 34), for Lock-Bar Steel Pipe (A 137 – 34) and for Riveted Steel and Wrought-Iron Pipe (A 138 – 34) have been submitted to the A.S.A. for advancement from American Tentative Standard to American Standard.

New Committees Organized.—Authorization was given the Society during the year by the American Standards Association to organize a new Sectional Committee on Petroleum Products and Lubricants with the A.S.T.M. as sole sponsor. This sectional committee is to supersede the present Sectional Committee Z11 on Methods of Testing Petroleum Products and Lubricants and Sectional Committee K19 on Specifications for Fuel Oils (Including Diesel Fuel). The new sectional committee will have a broader scope than the previous committees and at the same time will be organized in such a way as to function more efficiently as a reviewing and coordinating body. Invitations have been extended to the various interested bodies to be represented on this committee and it is expected that organization will be effected within the next few months.

A committee of considerable interest to the Society has recently been authorized by the Standards Council of the American Standards Association, namely, the Building Code Correlating Committee. One of the purposes in organizing this committee is to take over some of the functions of the former Department of Commerce Building Code Committee which has recently been discontinued. The Society will be represented on this committee by Mr. R. P. Miller with the Assistant Secretary as alternate.

On the new Sectional Committee C61 on Electric and Magnetic Magnitudes and Units, functioning under A.S.A. procedure, the Society has appointed as its representatives, Mr. H. L. Curtis and Mr. W. J. Shackelton.

Since the work of the Sectional Committee on Recommended Practice for Brick Masonry is now being revived and is expected to include in the immediate future some discussion of mortars for masonry, the Society has appointed an additional representative on the committee, namely, Mr. R. E. Davis, for the purpose of tying in effectively the work of the Society's Committee C-12 on Mortars for Unit Masonry. Mr. J. W. Whittemore has been designated as alternate.

Respectfully submitted on behalf of the committee,

T. R. LAWSON,
Chairman.

C. L. WARWICK,
Ex-officio Secretary.

A.S.T.M.
TENTATIVE STANDARDS

ISSUED OR REVISED, 1935

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward its adoption as standard.

Members of the Society and others are invited to direct written criticism of any of these Tentative Standards to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

TENTATIVE SPECIFICATIONS

FOR

CARBON-STEEL PLATES FOR BOILERS AND OTHER PRESSURE VESSELS FOR STATIONARY SERVICE[1]

A.S.T.M. Designation: A 70 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1916; ADOPTED IN AMENDED FORM, 1924; REVISED, 1927, 1933; REISSUED AS TENTATIVE, 1935.[2]

Scope

1. These specifications cover two classes of steel for boilers and other pressure vessels for stationary service, namely: flange and firebox, and are intended to apply to plates, $\frac{3}{16}$ to 4 in., inclusive, in thickness.

Process

2. The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Heat Treatment

3. (*a*) Plates over 2 in. in thickness, before being fabricated, shall be uniformly heat treated to produce grain refinement. If this treatment is not done at the rolling mill the testing shall be carried out in accordance with Paragraph (*b*).

(*b*) When a fabricator, who is equipped to properly perform the work, elects to do the required heat treatment for grain refinement he shall so indicate on his orders to the mill and he shall accept the plates on the basis of the mill tests. The plate manufacturer shall make the tests herein specified, the tension and bend test specimens to be prepared from full thickness pieces heat treated under conditions he considers appropriate for grain refinement and to give the test requirements. The manufacturer shall inform the fabricator of the procedure followed in treating the pieces at the mill for guidance in treating the plates. The required physical properties shall be determined after heat treatment of the plates on specimens prepared from pieces similarly and simultaneously treated with the plates. Pieces for two complete sets of such tests shall be provided from each plate as rolled.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications are in effect a revision of, and replace the former Standard Specifications for Boiler and Firebox Steel for Stationary Service (A.S.T.M. Designation: A 70 - 33), which standard was accordingly discontinued in 1935.

[2] **Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.**

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

		FLANGE	FIREBOX
Carbon, max., per cent	For plates ¾ in. and under in thickness	....	0.25
	For plates over ¾ to 2 in., inclusive, in thickness	....	0.30
	For plates over 2 to 4 in., inclusive, in thickness	....	0.33
Manganese, max., per cent		0.80	0.80
Phosphorus, max., per cent	Acid	0.05	0.04
	Basic	0.04	0.035
Sulfur, max., per cent		0.05	0.04

Ladle Analyses

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 4.

Check Analyses

6. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled (Note). The chemical composition thus determined shall conform to the requirements specified in Section 4.

NOTE.—The term "plate as rolled," used here and in Sections 11 (*c*) and 12, refers to the unit plate rolled from a slab or directly from an ingot in its relation to the location and number of specimens; not to its condition.

Tension Tests

7. (*a*) The material shall conform to the following requirements as to tensile properties:

	FLANGE	FIREBOX
Tensile strength, lb. per sq. in	55 000 to 65 000	55 000 to 65 000
Yield point, min., lb. per sq. in	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1\,500\,000^{a}}{\text{tens. str.}}$	$\frac{1\,550\,000^{a,b}}{\text{tens. str.}}$
Elongation in 2 in., min., per cent[c]	$\frac{1\,700\,000^{d}}{\text{tens. str.}}$	$\frac{1\,750\,000^{d}}{\text{tens. str.}}$

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[a] See Section 8 (*a*) and (*c*).

[b] See Paragraph (*c*).

[c] When specimen shown in Fig. 2 is used; see Section 11 (*e*).

[d] See Section 8 (*b*).

(*b*) Tensile strength only need be determined on the tension test specimen taken from the top of firebox plates, and it shall not exceed 70,000 lb. per sq. in.

(*c*) Should the rule in Paragraph (*a*) for minimum elongation in 8 in. for firebox steel give a value of less than 25 per cent, the minimum allowable elongation shall be 25 per cent, subject to the modifications of Section 8 (*a*).

(*d*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine.

Modifications in Elongation

8. (*a*) For material over $\frac{3}{4}$ to 2 in., inclusive, in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 7 (*a*) and (*c*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 21 per cent for flange steel and 22 per cent for firebox steel.

(*b*) For material over $2\frac{1}{2}$ in. in thickness, a deduction from the percentage of elongation in 2 in. specified in Section 7 (*a*) of 0.5 per cent shall be made for each increase of $\frac{1}{2}$ in. of the specified thickness above $2\frac{1}{2}$ in.

(*c*) For material $\frac{1}{4}$ in. and under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests

9. (*a*) The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion around a pin, the diameter of which shall have the following relation to the thickness of the specimen:

THICKNESS OF MATERIAL	DIAMETER OF PIN ABOUT WHICH SPECIMEN IS BENT (t = thickness of specimen)
1 in. and under	1 t
over 1 to $1\frac{1}{2}$ in., inclusive	$1\frac{1}{2}$ t
over $1\frac{1}{2}$ to 3 in., inclusive	2 t
over 3 to 4 in., inclusive	$2\frac{1}{2}$ t

(*b*) *Bend Test for Universal Edge Rolled Plates When Permitted for Double-Butt-Strap Construction.*—The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion around a pin, the diameter of which shall have the following relation to the thickness of the specimen:

THICKNESS OF MATERIAL	DIAMETER OF PIN ABOUT WHICH SPECIMEN IS BENT (t = thickness of specimen)
1 in. and under	$1\frac{1}{2}$ t
over 1 to $1\frac{1}{2}$ in., inclusive	$2\frac{1}{2}$ t
over $1\frac{1}{2}$ to 2 in., inclusive	3 t

Homogeneity Test

10. (*a*) The object of the homogeneity test, which is required for firebox steel only, is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. The fractured surface of the specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. in length for plates $\frac{3}{4}$ in. and under in thickness, nor more than $\frac{3}{8}$ in. in length for plates over $\frac{3}{4}$ in. in thickness, in any of the fractures obtained in accordance with Para-

graph (*b*). Each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

(*b*) The test may be made on a broken tension test specimen when an 8-in. gage length specimen is used. For plates over 2 in. in thickness, the specimen for homogeneity test shall be taken adjacent, sidewise or lengthwise, to the top tension test specimen. For plates $\frac{3}{4}$ in. and under in thickness the specimen shall be nicked or grooved transversely, in three places, about $\frac{1}{16}$ in. deep. The first groove shall be 2 in. from the square end, and each succeeding groove on the opposite side about 2 in. from the preceding one. For plates over $\frac{3}{4}$ to $2\frac{1}{8}$ in., inclusive, in thickness the specimen may be grooved $\frac{1}{8}$ in. deep, at one place on one side. For plates over $2\frac{1}{8}$ in. in thickness the specimen may be grooved at one place on both sides to leave a fracture which will include the horizontal axis of the plate and have a face at least 2 in. in depth. The specimens shall be broken at each groove with a hammer or press, the bending being away from the groove.

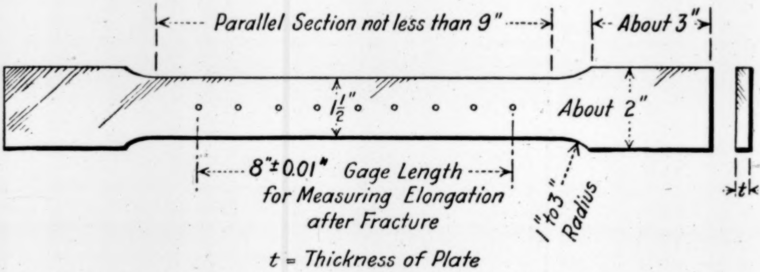
Parallel Section not less than 9"
About 3"
$1\frac{1}{2}$"
About 2"
8"±0.01" Gage Length for Measuring Elongation after Fracture
1" to 3" Radius
t
t = Thickness of Plate

FIG. 1.—Standard 8-in. Gage Length Test Specimen.

Test Specimens

11. (*a*) For plates 2 in. and under in thickness the test specimens shall be prepared for testing from the material in its rolled condition.

(*b*) For plates over 2 in. in thickness the test specimens shall be prepared from the material in its heat-treated condition, or from full thickness samples similarly and simultaneously treated.

(*c*) Tension test specimens for firebox steel shall be taken from the top and bottom corners of the plate as rolled, parallel to its longitudinal axis and for flange steel from the bottom corner of the plate only. Bend test specimens shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis. (See Note under Section 6.)

(*d*) For plates 2 in. and under in thickness, tension and bend test specimens shall be the full thickness of the material and shall be machined to the form and dimensions shown in Fig. 1; or the bend test specimens may be machined with both edges parallel.

(*e*) For plates over 2 in. in thickness, the axis of each tension test specimen shall be located midway between the center and the top or bottom surface of the plate; and these specimens shall be machined to the form and dimensions shown in Fig. 2. The bend test specimens shall be at least 1½ in. in width, with both edges parallel, and may be reduced to 2 in. in thickness; but shall have one surface as rolled.

(*f*) The sides of the bend test specimen may have the corners rounded to a radius of about $\frac{1}{16}$ in. for plates 2 in. and under in thickness, and to about $\frac{1}{8}$ in. for plates over 2 in. in thickness.

Number of Tests

12. (*a*) Two tension and one bend test shall be made from each firebox steel plate as rolled. One tension and one bend test shall be made from each flange steel plate as rolled. (See Note under Section 6.)

(*b*) If any specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

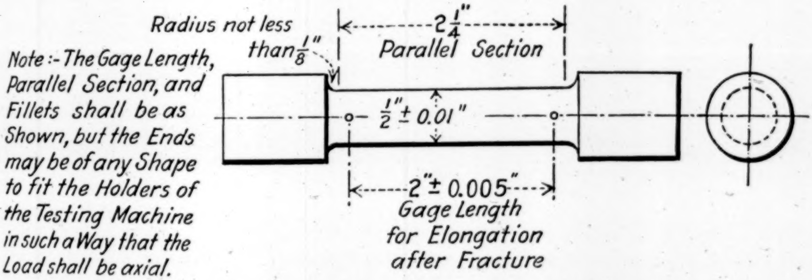
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Permissible Variations in Thickness and Weight

13. (*a*) The thickness of each plate shall not vary more than 0.01 in. under the thickness ordered.

(*b*) The overweight of each lot[1] of plates 2 in. and under in thickness in each shipment shall not exceed the amount given in Table I One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*c*) Each plate over 2 in. in thickness shall conform to the permissible variations over ordered thickness given in Table II.

Finish

14. The finished material shall be free from injurious defects and shall have a workmanlike finish.

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[1] The term "lot" as applied to plates 2 in. and under in thickness means all the plates of each group width and group thickness

Marking

15. (*a*) Except as specified in Paragraph (*b*), the name or brand of the manufacturer, the manufacturer's test identification number, class, and lowest tensile strength specified in Section 7 (*a*) shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$, excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$, excl.
$\frac{3}{16}$ to $\frac{1}{4}$, excl.	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ to $\frac{1}{4}$, excl.
$\frac{1}{4}$ to $\frac{5}{16}$, excl.	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ to $\frac{5}{16}$, excl.
$\frac{5}{16}$ to $\frac{3}{8}$, excl.	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ to $\frac{3}{8}$, excl.
$\frac{3}{8}$ to $\frac{7}{16}$, excl.	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ to $\frac{7}{16}$, excl.
$\frac{7}{16}$ to $\frac{1}{2}$, excl.	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ to $\frac{1}{2}$, excl.
$\frac{1}{2}$ to $\frac{5}{8}$, excl.	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ to $\frac{5}{8}$, excl.
$\frac{5}{8}$ to $\frac{3}{4}$, excl.	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ to $\frac{3}{4}$, excl.
$\frac{3}{4}$ to 1, excl.	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ to 1, excl.
1 to 2, incl.	2.5	2.5	3	3.5	4	4.5	5	6	7	1 to 2, incl

TABLE II.—PERMISSIBLE VARIATIONS OVER ORDERED THICKNESS OF PLATES OVER 2 IN. IN THICKNESS.

NOTE.—Each plate shall not vary more than 0.01 in. under the ordered thickness.

Ordered Thickness, in.	Permissible Excess in Thickness, In.					
	Width, in.					
	Up to 36, excl.	36 to 60, excl.	60 to 84, excl.	84 to 120, excl.	120 to 132, excl.	132 to 144, excl.
Over 2 to 3, excl.	0.062 ($\frac{1}{16}$)	0.094 ($\frac{3}{32}$)	0.109 ($\frac{7}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)
3 to 4, excl.	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)	0.109 ($\frac{7}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)
4	0.094 ($\frac{3}{32}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)	0.141 ($\frac{9}{64}$)	0.156 ($\frac{5}{32}$)	0.172 ($\frac{11}{64}$)

(*b*) For plates under $\frac{1}{4}$ in. in thickness, the marking specified in Paragraph (*a*) shall be legibly stenciled instead of stamped.

Inspection

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed.

to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6, shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected material, shall be preserved for two weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

HIGH TENSILE STRENGTH CARBON-STEEL PLATES FOR PRESSURE VESSELS[1]

(PLATES 2 IN. AND UNDER IN THICKNESS)

A.S.T.M. Designation: A 149 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1935.[2]

Scope

1. These specifications cover two grades of high tensile strength carbon-steel plates $\frac{3}{16}$ in. to 2 in., inclusive, in thickness, of flange and firebox qualities, for boilers and other pressure vessels. The term grade is used to distinguish between different tensile ranges.

Process

2. The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Chemical Composition

3. The steel shall conform to the following maximum requirements as to chemical composition:

		GRADE A	GRADE B
Carbon, per cent	for plates $\frac{3}{4}$ in. and under in thickness	0.30	0.32
	for plates over $\frac{3}{4}$ in. in thickness	0.33	0.35
Manganese, per cent		0.90	0.90
Phosphorus, per cent	Flange	0.04	0.04
	Firebox	0.035	0.035
Sulfur, per cent	Flange	0.05	0.05
	Firebox	0.04	0.04
Silicon, per cent		0.25	0.25

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Revision accepted by Committee E-10 on Standards, August 22, 1935.

Ladle Analysis

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analysis

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

Tension Tests

6. (*a*) The material shall conform to the following requirements as to tensile properties:

		GRADE A	GRADE B
Tensile strength, lb. per sq. in.		65 000 to 77 000	70 000 to 82 000
Yield point, min., lb. per sq. in.		0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent	Flange	$\frac{1\ 550\ 000}{\text{tens. str.}}$[a]	$\frac{1\ 550\ 000}{\text{tens. str.}}$[a]
	Firebox	$\frac{1\ 600\ 000}{\text{tens. str.}}$[a]	$\frac{1\ 600\ 000}{\text{tens. str.}}$[a]

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[a] See Section 7 (*a*) and (*b*).

(*b*) Tensile strength only need be determined on the tension test specimen taken from the top of firebox plates, and it shall not exceed 79,000 lb. per sq. in. for Grade A nor 84,000 lb. per sq. in. for Grade B.

(*c*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine.

Modification in Elongation

7. (*a*) For plates over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in. to a minimum of 18 per cent for flange steel and 19 per cent for firebox steel.

(*b*) For material $\frac{1}{4}$ in. and under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests

8. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion around a

pin, the diameter of which shall have the following relation to the thickness of the specimen:

	RATIO: $\frac{\text{PIN DIAMETER}}{\text{THICKNESS OF SPECIMEN}}$	
THICKNESS OF MATERIAL	Grade A	Grade B
Up to 1 in., inclusive	$1\frac{1}{2}$	2
Over 1 to $1\frac{1}{2}$ in., inclusive	2	2
Over $1\frac{1}{2}$ to 2 in., inclusive	2	$2\frac{1}{2}$

Homogeneity Tests

9. (*a*) The object of the homogeneity test, which is required for firebox steel only, is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. The fractured surface of the specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. in length for plates $\frac{3}{4}$ in. and under in thickness, nor more than $\frac{3}{8}$ in. in length for plates over $\frac{3}{4}$ in. to 2 in. in thickness, in any of the fractures obtained in accordance with Paragraph (*b*). Each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

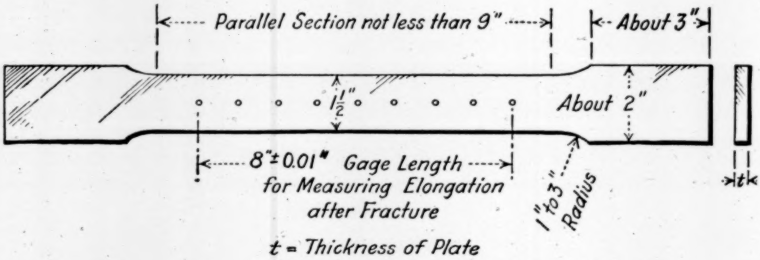
Parallel Section not less than 9"
About 3"
1/2"
About 2"
8" ± 0.01" Gage Length for Measuring Elongation after Fracture
1" to 3" Radius
t
t = Thickness of Plate

FIG. 1.—Standard 8-in. Gage Length Test Specimen.

(*b*) The test may be made on a broken tension test specimen. For plates $\frac{3}{4}$ in. and under in thickness the specimen shall be nicked or grooved transversely in three places, about $\frac{1}{16}$ in. deep. The first groove shall be 2 in. from the square end, and each succeeding groove on the opposite side about 2 in. from the preceding one. The specimen shall be broken at each groove in succession with a hammer or press, the bending being away from the groove. For plates over $\frac{3}{4}$ in. to 2 in., inclusive, in thickness, the specimen may be grooved about $\frac{1}{8}$ in. deep at one place on one side.

Test Specimens

10. (*a*) Tension test specimens for firebox material shall be taken from the top and bottom corners of the plate as rolled, parallel to its

longitudinal axis, and for flange material from the bottom corner of the plate only. The bend test specimen shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel. The sides of the bend test specimen may have the corners rounded to a radius of about $\frac{1}{16}$ in.

Number of Tests

11. (*a*) Two tension and one bend test shall be made from each firebox steel plate as rolled. One tension and one bend test shall be made from each flange steel plate as rolled.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$, excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$, excl.
$\frac{3}{16}$ to $\frac{1}{4}$, "	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ to $\frac{1}{4}$, "
$\frac{1}{4}$ to $\frac{5}{16}$, "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ to $\frac{5}{16}$, "
$\frac{5}{16}$ to $\frac{3}{8}$, "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ to $\frac{3}{8}$, "
$\frac{3}{8}$ to $\frac{7}{16}$, "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ to $\frac{7}{16}$, "
$\frac{7}{16}$ to $\frac{1}{2}$, "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ to $\frac{1}{2}$, "
$\frac{1}{2}$ to $\frac{5}{8}$, "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ to $\frac{5}{8}$, "
$\frac{5}{8}$ to $\frac{3}{4}$, "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ to $\frac{3}{4}$, "
$\frac{3}{4}$ to 1, "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ to 1, "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Permissible Variations

12. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

Finish

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

Marking

14. (*a*) Except as specified in Paragraph (*b*), the name or brand of the manufacturer, the manufacturer's test identification number, class and lowest tensile strength specified shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

(*b*) For plates under $\frac{1}{4}$ in. in thickness, the marking specified in Paragraph (*a*) shall be legibly stenciled instead of stamped.

Inspection

15. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5, shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

17. Samples tested in accordance with Section 5 which represent rejected material, shall be preserved for two weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
HIGH TENSILE STRENGTH CARBON-STEEL PLATES FOR FUSION-WELDED PRESSURE VESSELS[1]

(PLATES OVER 2 IN. UP TO AND INCLUDING 4 IN. IN THICKNESS)

A.S.T.M. Designation: A 150 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1935.[2]

Scope

1. These specifications cover two grades of high tensile strength carbon-steel plates over 2 in. and up to and including 4 in. in thickness, of firebox quality, suitable for fusion-welded pressure vessels. The term grade is used to distinguish between different tensile ranges.

Process

2. The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Heat Treatment

3. (*a*) All plates, before being fabricated, shall be uniformly heat treated to produce grain refinement. If this treatment is not done at the rolling mill the testing shall be carried out in accordance with Paragraph (*b*).

(*b*) When a fabricator, who is equipped to properly perform the work, elects to do the required heat treatment for grain refinement he shall so indicate on his orders to the mill and he shall accept the plates on the basis of the mill tests. The plate manufacturer shall make the tests herein specified, the tension and bend test specimens to be prepared from full thickness pieces heat treated under conditions he considers appropriate for grain refinement and to give the test requirements. The manufacturer shall inform the fabricator of the procedure followed in treating the pieces at the mill for guidance in treating the plates. The required physical properties shall be determined after heat treatment of the plates on specimens prepared from pieces similarly and simultaneously treated with the plates.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Revision accepted by Committee E-10 on Standards, August 22, 1935.

Pieces for two complete sets of such tests shall be provided from each plate as rolled.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

Carbon, max., per cent		0.35
Manganese, per cent		0.50 to 0.90
Phosphorus, max., per cent	Acid	0.04
	Basic	0.035
Sulfur, max., per cent		0.04
Silicon, max., per cent		0.25

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled (Note). The chemical composition thus determined shall conform to the requirements specified in Section 4.

NOTE.—The term "plate as rolled" used here and in Sections 11 (*b*) and 12 (*a*) refers to the unit plate rolled from a slab or directly from an ingot in its relation to the location and number of specimens; not to its condition.

Tension Tests

7. (*a*) The material shall conform to the following requirements as to tensile properties:

	GRADE A	GRADE B
Tensile strength, lb. per sq. in.	65 000 to 77 000	70 000 to 82 000
Yield point, min., lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 2 in., min., per cent	$\frac{1\,750\,000^{a}}{\text{tens. str.}}$	$\frac{1\,750\,000^{a}}{\text{tens. str.}}$

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[a] See Section 8.

(*b*) Tensile strength only need be determined on the tension test specimen taken from the top of the plates, and it shall not exceed 79,000 lb. per sq. in. for Grade A, nor 84,000 lb. per sq. in. for Grade B.

(*c*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine.

Modifications in Elongation

8. For plates over 2½ in. in thickness, a deduction from the percentage of elongation specified in Section 7 (*a*) of 0.5 per cent

shall be made for each increase of ½ in. of the specified thickness above 2½ in.

Bend Tests

9. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion around a pin, the diameter of which shall have the following relation to the thickness of the specimen. When the test is made on a specimen reduced in thickness, the rolled surface shall be on the outer curve of the bend:

THICKNESS OF MATERIAL	RATIO: PIN DIAMETER / THICKNESS OF SPECIMEN	
	GRADE A	GRADE B
Up to 3 in., inclusive	2	2½
Over 3 to 4 in., inclusive	2½	3

Homogeneity Test

10. (*a*) The object of the homogeneity test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. The fractured surface of the specimen shall not show any single seam or cavity more than ⅜ in. in length for plates 2 to 4 in. in thickness. Each fracture shall be examined and the length of the seams and cavities determined, a pocket lens being used if necessary.

(*b*) The specimen for homogeneity test shall be taken adjacent, sidewise or lengthwise, to the top tension test specimen. The specimen shall be nicked or grooved transversely at one place on one side about ¼ in. deep for plates up to 2¼ in. in thickness, and broken with a hammer or press, the bending being away from the groove. For plates over 2¼ in. in thickness the specimen may be grooved at one place on both sides to leave a fracture which will include the horizontal axis of the plate and have a face at least 2 in. in depth.

Test Specimens

11. (*a*) The tests shall represent the plates as heat treated for use. The test specimens shall be prepared from the material in its heat-treated condition, or from full thickness samples similarly and simultaneously treated.

(*b*) Tension test specimens shall be taken from the top and bottom corners of the plate as rolled (see Note under Section 6), parallel to its longitudinal axis. The axis of the test specimen shall be located midway between the center and the top or bottom surface of the plate. The bend test specimen shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis.

(*c*) Tension test specimens shall be machined to the form and dimensions shown in Fig. 1.

(*d*) The bend test specimen shall be at least 1½ in. in width, with both edges machined parallel. For material over 2 in. in thickness the specimen may be reduced to 2 in. in thickness, but it shall have one surface as rolled The sides of the bend test specimen may have the corners rounded to a radius of about ⅛ in.

Number of Tests

12. (*a*) Two tension and one bend test shall be made from each plate as rolled (see Note under Section 6).

(*b*) If any test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

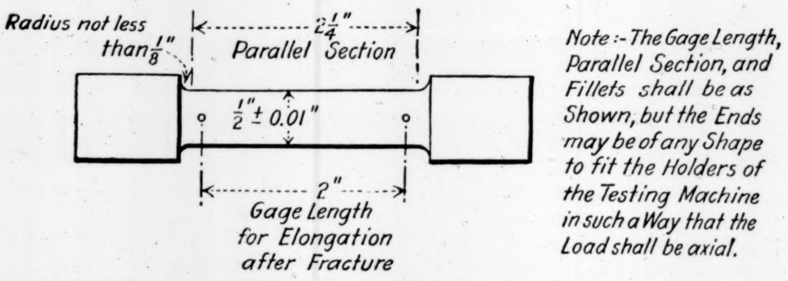
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2"
Gage Length for Elongation after Fracture
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Permissible Variations in Thickness

13. The thickness of each plate shall not vary more than 0.01 in. under that ordered. The permissible variations over the ordered thickness shall not exceed the amounts given in Table I.

Finish

14. The finished material shall be free from injurious defects and shall have a workmanlike finish.

Marking

15. The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest tensile strength for the grade specified in Section 7 (*a*) shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from

each end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

Inspection

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—PERMISSIBLE VARIATIONS OVER ORDERED THICKNESS.

Ordered Thickness, in.	Permissible Excess in Thickness, in.					
	Width, in.					
	Up to 36, excl.	36 incl., to 60 excl.	60 incl., to 84 excl.	84 incl., to 120 excl.	120 incl., to 132 excl.	132 incl., to 144 excl.
Over 2 to 3 excl.............	0.062 ($\frac{1}{16}$)	0.094 ($\frac{3}{32}$)	0.109 ($\frac{7}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)
3 incl., to 4 excl...........	0.078 ($\frac{5}{64}$)	0.094 ($\frac{3}{32}$)	0.109 ($\frac{7}{64}$)	0.125 ($\frac{1}{8}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)
4 incl., to 6 excl...........	0.094 ($\frac{3}{32}$)	0.125 ($\frac{1}{8}$)	0.141 ($\frac{9}{64}$)	0.141 ($\frac{9}{64}$)	0.156 ($\frac{5}{32}$)	0.172 ($\frac{11}{64}$)
6 incl., to 8 excl...........	0.109 ($\frac{7}{64}$)	0.125 ($\frac{1}{8}$)	0.156 ($\frac{5}{32}$)	0.156 ($\frac{5}{32}$)	0.172 ($\frac{11}{64}$)	....
8 incl., to 10 excl...........	....	0.172 ($\frac{11}{64}$)	0.187 ($\frac{3}{16}$)	0.187 ($\frac{3}{16}$)	....	....
10 incl., to 12 excl...........	....	0.187 ($\frac{3}{16}$)	0.234 ($\frac{15}{64}$)	0.234 ($\frac{15}{64}$)	....	....
12 incl., to 15 excl...........	....	0.219 ($\frac{7}{32}$)	0.250 ($\frac{1}{4}$)	....	....	....

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6, shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6 which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
COLD-ROLLED STRIP STEEL[1]

A.S.T.M. Designation: A 109 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1926; Revised, 1927, 1934, 1935.[2]

The name "Cold-Rolled Strip Steel" covers a very wide range of material. After annealing the metal, any amount of cold work may be done by cold rolling, ranging from a pass between the "levelling" or "breaker rolls" which does not appreciably reduce the gage of the metal, on through various light "pincher-passes" between planishing rolls, up to regular cold rolling that may affect as much as a 50 per cent reduction in thickness. Every different amount of reduction produces a different set of physical properties. Differences in chemical composition, history of the steel itself, and its annealing, likewise cause variations in the final properties.

It is impractical to set up a multitude of specifications for cold-rolled strip steel to cover all minor gradations of "temper" that have come into use. So it is the established custom in the trade to classify this material rather roughly into five grades or tempers, ranging from No. 1, full hard, to No. 5, dead soft. Some manufacturers add a Grade No. 6 which is similar to Grade No. 5 but with special selection of chemical composition to attain the maximum of ductility. Each temper is suitable for a general type of work, as indicated in the table given in the Appendix.

The demarcation between cold-rolled sheets and cold-rolled strip is as follows:

Cold-Rolled Sheets:

(*a*) All widths 24 in. and wider.

(*b*) Over 12 in. up to 23$\frac{15}{16}$ in. in width which are not in coils and are 0.028 in. and under in thickness.

Cold-Rolled Strip:

(*a*) All widths 12 in. and narrower.

(*b*) Over 12 in. up to 23$\frac{15}{16}$ in. in width which are in coils; and both flat and coiled stock 0.029 in. and over in thickness.

The bend test is the only physical property prescribed in these specifications. A tabulation of approximate values for tensile strength, elongation, Rockwell hardness, and depth of cup corresponding to the five commercial tempers of cold-rolled strip steel is presented in the Appendix as a matter of general information.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

Scope

1. These specifications cover five grades or tempers of commercial cold-rolled, strip steel as follows:

Grade No. 1, or "Hard" temper;
Grade No. 2, or "Half-Hard" temper;
Grade No. 3, or "Quarter-Hard" temper;
Grade No. 4, or "Soft or Planished" temper;
Grade No. 5, or "Dead Soft" temper.

Selection of Temper

2. These five grades or tempers of cold-rolled strip steel cover all uses, from plain flat blanking, through easy bending, shallow drawing and stamping, up to fairly deep drawing, to drifting and very deep drawing. Each temper is capable of subdivision for obtaining products especially suited to particular uses (Note).

NOTE.—By consulting with the manufacturer, the purchaser can obtain a closely graded product for any particular job. For difficult, and indeed for most applications, this is the best procedure.

Process

3. The steel for Grades Nos. 3, 4 and 5 shall be made by either or both of the following processes: open-hearth or electric-furnace. Rimmed steel is in general use, but killed steel may be used, although it is generally a little harder than the rimmed steel.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:[a]

GRADES NOS. 1 AND 2

Carbon, per cent	0.04 to 0.12 and for some uses up to 0.25 max. will be permissible.

GRADES NOS. 3, 4 AND 5

Carbon, per cent	0.04 to 0.12
Manganese, per cent	0.30 to 0.50
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.055

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[a] Where cold-rolled strip steel is to be used for parts that are to be case-hardened, this fact should be made known to the producer who will regulate the analysis more closely, especially in the case of Grades Nos. 1 and 2.

Samples for Chemical Analysis

5. Samples for chemical analysis shall be taken by machining the entire cross-section of the strip.

Bend Tests

6. (*a*) The bend test specimens shall stand being bent cold as specified below without cracking on the outside of the bent portion:

GRADE	TEMPER	
No. 1	Hard	Not required to make bends in either direction of grain.
No. 2	Half Hard	Bend to a sharp[a] right angle across the grain.[b]
No. 3	Quarter Hard	Bend flat upon itself across the grain and to a sharp[a] right angle along the grain.[b]
No. 4	Soft or Planished	Bend flat upon itself both ways of the grain.[b]
No. 5	Dead Soft	Bend flat upon itself both ways of the grain.[b]

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[a] Edge of forming tool shall be slightly "broken" (that is beveled) to give the equivalent of a radius = 0.010 in., which may be considered as "commercially sharp."

[b] To bend across the grain means that the crease formed by the bend shall be at right angles to the length of the cold-rolled strip. To bend along the grain means that the crease formed by the bend shall be parallel with the length of the cold-rolled strip.

(*b*) *Bend Test Specimens.*—Bend test specimens shall be $\frac{1}{2}$ in. or more in width, and of any convenient length. The edges shall be rounded with a file to remove sharp corners and burrs due to shearing.

(*c*) *Number of Bend Tests.*—Three bend tests, if concordant, shall be considered representative of each coil (or strip) selected for test.

TABLE I.—PERMISSIBLE VARIATIONS IN THICKNESS OF COLD-ROLLED STRIP STEEL.

Specified Thickness, in.	Permissible Variations in Thickness, Over and Under, for Widths Given, in.							
	$\frac{3}{16}$ to 1, excl.	1 to 3, excl.	3 to 6	Over 6 to 9	Over 9 to 12	Over 12 to 16	Over 16 to 20	Over 20 to 24, excl.
Under 0.006	0.0005	0.0005	0.0005	......	......	......	......	......
0.006 to 0.010, excl	0.00075	0.00075	0.00075	......	......	......	......	......
0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015
0.011	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015
0.012	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.0015
Over 0.012 to 0.016, incl	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
Over 0.016 to 0.019, incl	0.001	0.001	0.001	0.0015	0.0015	0.002	0.002	0.002
Over 0.019 to 0.025, incl	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
Over 0.025 to 0.028, incl	0.001	0.0015	0.0015	0.002	0.002	0.002	0.0025	0.003
Over 0.028 to 0.034, incl	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
Over 0.034 to 0.039, incl	0.002	0.002	0.0025	0.003	0.003	0.003	0.003	0.003
Over 0.039 to 0.049, incl	0.002	0.002	0.0025	0.003	0.003	0.003	0.004	0.004
Over 0.049 to 0.068, incl	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004
Over 0.068 to 0.099, incl	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004
Over 0.099 to 0.160, incl	0.002	0.002	0.003	0.004	0.004	0.004	0.005	0.005
Over 0.160 to 0.249, incl	0.002	0.003	0.004	0.004	0.004	0.005	0.006	0.006

Permissible Variations in Thickness

7. The thickness of the strip shall not vary from the thickness specified by more than the permissible variations given in Table I. Cold-rolled strip 2 in. and under in width may be gaged at any point. Cold-rolled strip over 2 in. in width shall be gaged $\frac{3}{8}$ in. from the edge and may be thicker at the center (crown) than at the edge by the amounts shown in Table II.

Permissible Variations in Width

8. (*a*) Width tolerances vary according to the type "edge." The types of edge are as follows:

Edge No. 1.—A perfectly round or square smooth edge.
Edge No. 2.—Natural round edge.
Edge No. 3.—Square, produced by slitting, not filed. (The usual commercial edge.)
Edge No. 4.—Round edge, rolled.
Edge No. 5.—Square, produced by rolling or filing after slitting.
Edge No. 6.—Square edge, rolled.

(*b*) The width of the strip shall not vary from the width specified by more than the permissible variations given in Tables III, IV and V according to the type of edge.

TABLE II.—ADDITIONAL PERMISSIBLE THICKNESS AT CENTER (CROWN) OF COLD-ROLLED STRIP STEEL OVER 2 IN. IN WIDTH.

Specified Thickness, in.	Additional Permissible Thickness for Widths Given, in.		
	5 or Under	Over 5 to 12	Over 12 to 24, excl.
0.005 to 0.010	0.00075	0.001	0.0015
Over 0.010 to 0.025	0.001	0.0015	0.002
Over 0.025 to 0.065	0.0015	0.002	0.0025
Over 0.065 to 0.187	0.002	0.0025	0.003
Over 0.187 to 0.250	0.0025	0.003	0.004

Length

9. (*a*) Cold-rolled strip steel is usually furnished in coils, but may be ordered cut to lengths. When so ordered, the length of the strip shall not vary from the specified length by more than the permissible variations shown in Table VI.

(*b*) Cutting to definite lengths of 36 in. or over does not relieve the purchaser from scrap loss and short lengths will be included, cut to multiples, if so desired.

Straightness

10. The permissible camber shall be as follows:

WIDTH, IN.	CAMBER, IN.
1½ or under	½ in. in 8 ft.
Over 1½ in.	¼ in. in 8 ft.

Flatness

11. When flatness of strip steel is essential, it shall be so specified by the purchaser. Flatness shall be determined by placing the strips in 8-ft. lengths on a flat surface. No part of the strip shall rise more

TABLE III.—PERMISSIBLE VARIATIONS IN WIDTH FOR STRIP OF NO. 3 EDGE (MOST LARGELY USED).

Specified Width, in.	Permissible Variations in Width, Over and Under, for Thicknesses Given, in.			
	0.068 or under	Over 0.068 to 0.099	Over 0.099 to 0.160	Over 0.160 to 0.250, excl.
$\frac{3}{16}$ to $\frac{1}{2}$, excl.	0.005	0.008	0.010	.....
$\frac{1}{2}$ to 6, incl.	0.005	0.008	0.010	0.016
Over 6 to 9, incl.	0.005	0.010	0.016	0.020
Over 9 to 12, incl.	0.010	0.010	0.016	0.020
Over 12 to 20, incl.	0.016	0.016	0.020	0.031
Over 20	0.020	0.020	0.020	0.031

TABLE IV.—PERMISSIBLE VARIATIONS IN WIDTH FOR STRIP OF NO. 2 EDGE (MILL EDGE).

Specified Width, in.	Permissible Variations in Width, Over and Under, for All Thicknesses, in.
2 or under	$\frac{1}{32}$ (0.031)
Over 2 to 5, incl.	$\frac{3}{64}$ (0.047)
Over 5 to 10, incl.	$\frac{5}{64}$ (0.078)
Over 10 to 15, incl.	$\frac{3}{32}$ (0.094)
Over 15 to 20, incl.	$\frac{1}{8}$ (0.125)
Over 20 to 24, excl.	$\frac{5}{32}$ (0.156)

TABLE V.—PERMISSIBLE VARIATIONS IN WIDTH FOR STRIP OF EDGES NOS. 1, 4, 5 AND 6.

Edge	Description	Thickness, in.	Width, in.	Permissible Variations in Width, Over and Under, in.
No. 1	Perfectly round or square smooth edge	$\frac{1}{16}$ or under	$\frac{9}{32}$ or under	0.005
No. 1		$\frac{3}{32}$ or under	Over $\frac{9}{32}$ to $\frac{3}{4}$, incl.	0.005
No. 1		$\frac{1}{8}$ or under	Over $\frac{3}{4}$ to 5, incl.	0.005
No. 4	Round edge, rolled	$\frac{3}{16}$ or under	$\frac{1}{2}$ or under	0.010
No. 4		0.025 to $\frac{3}{16}$, incl.	Over $\frac{1}{2}$ to 1, incl.	0.015
No. 4		0.025 to $\frac{1}{4}$, incl.	Over 1 to 2, incl.	0.025
No. 4		0.035 to $\frac{1}{4}$, incl.	Over 2 to 4, incl.	$\frac{3}{64}$
No. 4		0.047 to $\frac{1}{4}$, incl.	Over 4 to 6, incl.	$\frac{3}{64}$
No. 5	Square rolled or filed after slitting	$\frac{1}{16}$ or under	$\frac{9}{32}$ or under	0.005
No. 5		$\frac{3}{32}$ or under	Over $\frac{9}{32}$ to $\frac{3}{4}$, incl.	0.005
No. 5		$\frac{1}{8}$ or under	Over $\frac{3}{4}$ to 5, incl.	0.005
No. 5		0.008 to $\frac{1}{8}$, incl.	Over 5 to 9, incl.	0.010
No. 5		0.015 to 0.105, incl.	Over 9 to 20, incl.	0.010
No. 5		0.023 to 0.080, incl.	Over 20 to 24, excl.	0.015
No. 6	Square edge, rolled	$\frac{3}{16}$ or under	$\frac{1}{2}$ or under	0.010
No. 6		0.025 to $\frac{3}{16}$, incl.	Over $\frac{1}{2}$ to $\frac{15}{16}$, incl.	$\frac{1}{64}$
No. 6		0.025 to $\frac{1}{4}$, incl.	Over $\frac{15}{16}$ to 2, incl.	$\frac{1}{32}$
No. 6		0.025 to $\frac{1}{4}$, incl.	Over 2 to 6, incl.	$\frac{3}{64}$

than ¼ in. from the surface. It shall lie flat of its own weight, with no spring up from the flat surface.

Finish

12. Cold-rolled strip steel shall have a bright, smooth surface and shall be free from injurious defects.

Inspection

13. (*a*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture may be made prior to shipment, and such inspection shall be final. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE VI.—PERMISSIBLE VARIATIONS FROM SPECIFIED LENGTH.

Specified Length, ft.	Permissible Variations Over the Specified Length[a]	
	12 in. and Under in Width	Over 12 to 24 in., excl., in Width
2 to 5	¼	½
Over 5 to 10	½	¾
Over 10 to 20, incl	¾	1

[a] No variations under the specified length are permissible.

(*b*) In case material is not inspected at the place of manufacture, the purchaser may make the tests to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

14. (*a*) Unless otherwise specified, any rejections based on tests made in accordance with Section 13 (*b*) shall be reported within ten working days from the receipt of samples.

(*b*) Material which shows injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified within 90 days from the date of the receipt of the material by the purchaser.

(*c*) Samples tested in accordance with Section 13 (*b*) which represent rejected material, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX

To specify chemical composition and tensile strength, together with the percentage elongation in 2 in. does not sufficiently define the properties of cold-rolled strip steel to insure satisfactory material for use in many applications. Freedom from "stretcher strains" during forming, or perhaps equiaxed grains, may be vital, whereas, the tensile strength may be of only minor importance.

TABLE AI.—APPROXIMATE PHYSICAL PROPERTIES FOR VARIOUS TEMPERS OF COLD-ROLLED STRIP STEEL.

(These values are given as information only and are not intended as criteria for acceptance or rejection.)

Grade or Temper	Hardness (Rockwell "B" Scale), ($\frac{1}{16}$-in. Ball 100-kg. Load)	Depth of Cup for 0.050-in. Thickness of Strip, mm.[a]	Tensile Strength, lb. per sq. in.[b]	Elongation in 2 in. for 0.050-in. Thickness of Strip, per cent[c]	Remarks
No. 1 Hard	90 ± 6[d]	6 to 7	80 000 ± 12 000	3 ± 2	Intended for flat blanking only
No. 2 Half-Hard	80 ± 5	7 to 8	64 000 ± 8 000	9 ± 5	Intended for easy bending up to 90 deg. across the grain.[e] (No bending along the grain).
No. 3 Quarter-Hard	69 ± 5	8 to 9	54 000 ± 6 000	20 ± 7	For shallow drawing and stamping, where a very smooth surface is required. Bends 180 deg. across the grain. Bends up to 90 deg. along the grain.[e]
No. 4 Soft or Planished	58 ± 6	9 to 10½	48 000 ± 5 000	30 ± 6	For fairly deep drawing where no sign of surface strain[f] is permissible. Bends 180 deg. both ways of the grain.
No. 5 Dead Soft	45 ± 7	10 to 11½	44 000 ± 4 000	39 ± 6	For deep drawing where slight stretcher strains[f] are permissible. Also for drifting. (Erroneously called "extrusion.") Bends 180 deg. both ways of the grain.

[a] Cup depth varies with thickness of strip. For Grade No. 5, dead soft temper, the depth is given approximately by the formula, $D = 10.5 \text{ mm.} + 6.4 \log "t"$ (t = thickness in mm.). Other tempers vary in a similar way.

[b] Tensile properties are based on the standard tension test specimen for sheet metals, see Fig. 7 of the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials, see 1933 Book of A.S.T.M. Standards, Part I, p. 949.

[c] Elongation in 2 in. varies with thickness of strip. For Grade No. 5, dead soft temper, the percentage elongation $= 41 + 10 \log "t"$ (t = thickness in mm.). Other tempers vary in a similar way.

[d] For cold-rolled strip 0.069 in. and thinner in thickness the Rockwell B hardness range is 96 ± 6, with corresponding increase in tensile strength and drop in depth of cup test.

[e] To bend across the grain means that the crease formed by the bend shall be at right angles to the length of the cold-rolled strip. To bend along the grain means that the crease formed by the bend shall be parallel with the length of the cold-rolled strip.

[f] See third paragraph of the Appendix as to "age hardening" and the necessity for using steel promptly after rolling where stretcher strains are to be entirely absent.

The ideal condition is for a consumer to know for each job the optimum working range in Rockwell B hardness.[1] He can then accurately describe his needs to the producer. Many users are building up a background of data which will give them this advantage. Such well-informed buying is in no way objectionable to producing interests.

However, until a consumer has been able to standardize his requirements as a result of long experience and many physical tests checked against records of production, it is better to specify cold-rolled strip steel that shall be suitable for a given use (that is, suitable to make the particular article, as shown by sample, or by a blueprint giving method of manufacture). When the buyer specifies a list of physical properties he assumes the responsibility of such steel being satisfactory for the job.

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[1] In some cases, additional data as to "cup depth," "grain size," and need for "skin-rolling" to prevent stretcher strains are requisite.

While strip steel in the "dead soft" or annealed condition has the maximum ductility, it is unsuited to many forming operations due to its tendency to "stretcher strain." A small amount of cold rolling will prevent this, but the effect is only temporary, due to the phenomenon called "aging." In general, the higher the storage temperature, and the less the amount of skin-rolling, or temper-rolling, after final annealing, the shorter the elapsed time necessary for stretcher straining to recur. This is accompanied by an increase in hardness, yield point, and tensile strength and a decrease in ductility. For those jobs on which stretcher straining or breakage is likely to occur, the material should be fabricated as promptly as possible after temper cold rolling.

The following table of approximate physical properties corresponding to the five commercial tempers of cold-rolled strip steel, is presented as a matter of general information, to give a general view of the field covered. The limits of hardness, tensile strength, etc., in the table are not intended as criteria for acceptance or rejection unless specifically agreed to by the manufacturer when accepting the order. The exact processing by different manufacturers will naturally vary slightly, so that absolute identity cannot be expected in their commercial tempers of cold-rolled strip steel.

TENTATIVE SPECIFICATIONS
FOR
AXLE-STEEL CONCRETE REINFORCEMENT BARS[1]

A.S.T.M. Designation: A 160 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These specifications cover two classes of axle-steel concrete reinforcement bars: namely, plain and deformed.

(*b*) Plain and deformed bars are of three grades: namely, structural steel, intermediate and hard.

MANUFACTURE

Manufacture

2. The bars shall be rolled from carbon-steel axles for cars and locomotive tenders in the following standard journal sizes. No other axles or material shall be used:

	STANDARD JOURNAL SIZES
Carbon-steel axles	4¼ by 8 in. 5 by 9 in. 5½ by 10 in. 6 by 11 in.

CHEMICAL PROPERTIES AND TESTS

Carbon Determination

3. (*a*) The manufacturer shall make a determination for carbon of each axle received by him for manufacture into reinforcement bars. Based on these carbon determinations, all steel axles shall be stocked for subsequent rolling in separated lots by carbon range. The ranges of carbon shall be determined by the manufacturer as those best suited to meet the physical requirements.

(*b*) When requested by the purchaser, the manufacturer shall report the carbon range for each lot of bars furnished.

PHYSICAL PROPERTIES AND TESTS

Tension Tests

4. (*a*) The bars shall conform to the following requirements as to tensile properties:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

TENSILE REQUIREMENTS

Properties Considered	Plain Bars			Deformed Bars		
	Structural Steel Grade	Intermediate Grade	Hard Grade	Structural Steel Grade	Intermediate Grade	Hard Grade
Tensile strength, lb. per sq. in.	55 000 to 70 000	70 000 to 90 000	80 000 min.	55 000 to 70 000	70 000 to 90 000	80 000 min.
Yield point, min., lb. per sq. in.	33 000	40 000	50 000	33 000	40 000	50 000
Elongation in 8 in., min., per cent	$\frac{1\,400\,000}{\text{tens. str.}}$[a]	$\frac{1\,300\,000}{\text{tens. str.}}$[a] but not less than 16 per cent[a]	$\frac{1\,200\,000}{\text{tens. str.}}$[a]	$\frac{1\,250\,000}{\text{tens. str.}}$[a]	$\frac{1\,125\,000}{\text{tens. str.}}$[a] but not less than 14 per cent[a]	$\frac{1\,000\,000}{\text{tens. str.}}$[a]

[a] See Section 5.

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine.

Modifications in Elongation

5. (*a*) For plain and deformed bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 4 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in.

(*b*) For plain and deformed bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction from the percentages of elongation specified in Section 4 (*a*) of 0.5 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness or diameter below $\frac{7}{16}$ in.

Bend Tests

6. (*a*) The test specimen shall stand being bent cold around a pin without cracking. The following requirements for degree of bending and sizes of pins shall be observed:

BEND-TEST REQUIREMENTS

Thickness or Diameter of Bar	Plain Bars			Deformed Bars		
	Structural Steel Grade	Intermediate Grade	Hard Grade	Structural Steel Grade	Intermediate Grade	Hard Grade
Under $\frac{3}{4}$ in.	180 deg. d = t	180 deg. d = 2t	180 deg. d = 3t	180 deg. d = t	180 deg. d = 3t	180 deg. d = 4t
$\frac{3}{4}$ in. or over	180 deg. d = t	90 deg. d = 2t	90 deg. d = 3t	180 deg. d = 2t	90 deg. d = 3t	90 deg. d = 4t

NOTE.—d = the diameter of pin about which the specimen is bent.
t = the thickness or diameter of the specimen.

(*b*) Bend tests shall be made on specimens of sufficient length to insure free bending and with apparatus which provides:

(*1*) Continuous and uniform application of force throughout the duration of the bending operation;

(*2*) Unrestricted movement of the specimen at points of contact with the apparatus;

(*3*) Close wrapping of the specimen about the pin or mandrel during the bending operation.

(*c*) Other methods of bend testing may be used, but failures due to such methods shall not constitute a basis for rejection.

Test Specimens

7. Tension and bend test specimens from plain or deformed bars shall be of the full section of bars as rolled. For tension tests of deformed bars the sectional area used for unit stress determination shall be calculated from the length and weight of the test piece.

NOTE.—The area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 cu. in. of steel), or by dividing the weight per linear foot of specimen in pounds by 3.4 (weight of steel 1 in. square, 1 ft. long).

Number of Tests

8. (*a*) One tension and one bend test shall be made from each lot of ten tons or less of each size of bar rolled from each lot of axles assorted in groups as specified in Section 3.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 4 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT

Permissible Variations in Weight

9. The weight of any lot of bars shall not vary more than $3\frac{1}{2}$ per cent over and under the theoretical weight for bars $\frac{3}{8}$ in. and over in diameter nor more than 5 per cent over and under for bars under $\frac{3}{8}$ in. in diameter. The weight of any individual bar shall not vary more than 6 per cent under the theoretical weight for bars $\frac{3}{8}$ in. and over in diameter; nor more than 10 per cent under the theoretical weight for bars under $\frac{3}{8}$ in. in diameter. The theoretical weight of deformed bars shall be the theoretical weight of plain round or square bars of the same nominal size.

NOTE.—The term "lot" used in this paragraph means all the bars of the same nominal weight per linear foot in a carload.

FINISH

Finish

10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking

11. The brand of the manufacturer shall be legibly rolled on all deformed bars, and when loaded for mill shipment, all bars shall be properly separated and tagged with the manufacturer's test identification number.

INSPECTION AND REJECTION

Inspection

12. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

13. Bars which show injurious defects subsequent to their acceptance at the manufacturer's works, will be rejected, and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS
FOR
HEAT-TREATED CARBON- AND ALLOY-STEEL TRACK BOLTS[1]

A.S.T.M. Designation: A 183 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover two grades of heat-treated carbon-steel and heat-treated alloy-steel track bolts.

Process

2. (*a*) The steel for the bolts shall be made by either or both of the following processes: open-hearth or electric-furnace.

(*b*) The steel for the nuts shall be made by one or more of the following processes: open-hearth, electric-furnace, or acid-bessemer.

Chemical Composition

3. (*a*) The steel for the bolts shall conform to the following requirements as to chemical composition:

	CARBON STEEL	ALLOY STEEL[a]
Carbon, min., per cent	0.30	....
Phosphorus, max., per cent	0.04	0.04
Sulfur, max., per cent	0.06	0.05

[a] The type of alloy to be used shall be mutually agreed upon by the manufacturer and purchaser.

(*b*) The steel for the nuts shall conform to the screw-steel grades of the Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A.S.T.M. Designation: A 107 - 33) of the American Society for Testing Materials.[3]

(*c*) When high strength nuts are specified, the steel shall conform to a carbon range of 0.40 to 0.55 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications are in effect a tentative revision and proposed combination of the present Standard Specifications for Quenched Carbon-Steel Track Bolts (A.S.T.M. Designation: A 50 - 33) and Standard Specifications for Quenched Alloy-Steel Track Bolts (A.S.T.M. Designation: A 51 - 33) (see 1933 Book of A.S.T.M. Standards, Part I, pp. 131, 135), and when adopted as standard are intended to supersede the specifications mentioned.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] 1933 Book of A.S.T.M. Standards, Part I, p. 93.

Ladle Analysis

4. (*a*) A carbon determination shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 8-hr. period.

(*b*) An analysis of each melt of open-hearth or electric-furnace steel shall be made to determine the percentages of carbon, alloy when used, manganese, phosphorus and sulfur.

(*c*) The analyses prescribed in Paragraphs (*a*) and (*b*) shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

Check Analysis

5. An analysis may be made by the purchaser from a finished bolt representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 (*a*) by more than 25 per cent.

Tension Tests

6. (*a*) The finished bolts shall conform to the following minimum requirements as to tensile properties:

	CARBON STEEL		
	GRADE 1	GRADE 2	ALLOY STEEL
Tensile strength, lb. per sq. in.	100 000	110 000	115 000
Yield point, lb. per sq. in.	70 000	80 000	85 000
Elongation in 2 in., per cent	12	14	15
Reduction of area, per cent	25	35	40

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine operated at a cross-head speed not to exceed ⅛ in. per min. The tensile strength shall be determined at a speed of head not to exceed 1½ in. per min.

Test Specimens

7. The tension test specimen taken from the finished bolt shall conform to the dimensions shown in Fig. 1.

Bend Tests

8. (*a*) Full-size carbon-steel bolts, Grades 1 and 2, shall stand being bent cold through 45 deg. around a pin, the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion. If the bend test specimen breaks in the threaded portion, a retest shall be allowed.

(*b*) Full-size alloy-steel bolts shall stand being bent cold through 90 deg. around a pin, the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion. If the bend test specimen breaks in the threaded portion, a retest shall be allowed.

Strip Test

9. The threads of the nut shall not "strip" when the bolt, with nut fully mounted, is tested in tension to its yield point, the load being applied to the head of the bolt and the bearing side of the nut.

Number of Tests

10. (*a*) One tension, one bend, and one strip test shall be made from each lot of 50 kegs or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

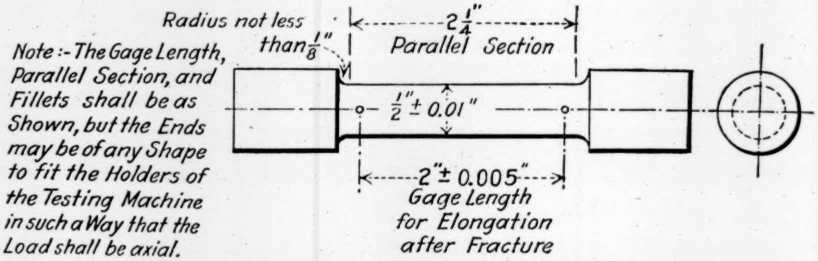
Radius not less than 1/8"
2 1/4"
Parallel Section
Note :- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Retest

11. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension, and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

Permissible Variations in Dimensions

12. (*a*) The bolts and nuts shall conform to the plans specified by the purchaser, subject to the following permissible variations:

		PERMISSIBLE VARIATIONS, IN.	
		OVER	UNDER
Bolt	Shank diameter for cut-thread bolt	$\frac{1}{64}$	$\frac{1}{32}$
	Neck dimensions	$\frac{1}{32}$	$\frac{1}{32}$
	Length under head	$\frac{1}{8}$	$\frac{1}{8}$
	Height and diameter of head	$\frac{1}{16}$	$\frac{1}{16}$
Nut	Width	......	0.05 × thread diameter of bolt
	Height	(0.016 × thread diameter of bolt) +0.012	(0.016 × thread diameter of bolt) +0.012

(*b*) The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size.

(*c*) The diameter of the rolled threads shall not exceed the diameter of the shank by more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over.

Finish

13. The bolts and nuts shall be neatly formed and free from fins or nicks. The head of the bolt shall be concentric with and firmly joined to the shank, with the under side at right angles to the axis of the bolt. It shall be free from injurious defects and shall have a workmanlike finish.

Threads and Thread Fit

14. The threads on bolts may be rolled or cut and shall be of the American Standard shape as shown in the American Standard for Screw Threads, A.S.A. No.: B1.1–1935, or subsequent revisions thereof. The nut shall have a hand-free fit from two to five turns in starting on the bolt, shall be wrench tight the remainder of the screw length of the nut, and shall show a minimum resistance of 20 lb. and a maximum of 70 lb. applied to a 24-in. wrench when the nut is fully engaged. Before packing, nuts shall be screwed on the bolts for enough turns to hold them in place until used.

Marking

15. (*a*) A letter or brand indicating the manufacturer together with the numerals "1" and "2" for Grades 1 and 2, respectively, and the letter "A" for alloy-steel bolts, shall be pressed on the head of the bolt when it is formed.

(*b*) All containers shall be marked by the manufacturer as follows:

- (*1*) Name of manufacturer.
- (*2*) Material (Grade 1, Grade 2, or Alloy).
- (*3*) Size of bolt (diameter and length).
- (*4*) Weight.

Inspection

16. The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to enable him to satisfy himself that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works shall be rejected and the manufacturer will be notified.

Rehearing

18. Samples tested in accordance with Section 5 which represent rejected bolts shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

CARBON-STEEL AND ALLOY-STEEL CASTINGS FOR RAILROADS[1]

A.S.T.M. Designation: A 87 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1922; ADOPTED IN AMENDED FORM, 1927; REISSUED AS TENTATIVE, 1935.[2]

Scope

1. These specifications cover carbon-steel and alloy-steel castings intended for locomotive and car equipment. Four grades of castings are covered: namely,

Grade A-1.—Castings of this grade as specified by the purchaser, not required to be annealed.

Grade A-2.—Castings of this grade as specified by the purchaser, required to be annealed.

Grade B.—Castings of this grade as specified by the purchaser, required to be annealed; such as truck side frames, bolsters, locomotive frames, locomotive driving and trailer wheel centers, and other parts to be subjected to high stresses.

Grade C.—Castings of this grade as specified by the purchaser, required to be annealed.

Process

2. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter, or crucible.

Heat Treatment

3. (*a*) All castings of Grades A-2, B, and C shall be annealed. The annealing treatment shall consist of normalizing or of full annealing, applied one or more times, all at the option of the manufacturer. Also at the option of the manufacturer, the annealing treatment may be followed by a tempering or drawing treatment, applied one or more times.

(*b*) *Normalizing.*—The procedure for normalizing shall consist of allowing the castings to cool after pouring, to a temperature below the critical range; reheating to the proper temperature and for the required time as a preliminary procedure for the ultimate refinement of the grain; and cooling thereafter in still air at room temperature.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications are in effect a revision of and replace the former Standard Specifications for Carbon-Steel Castings for Railroads (A.S.T.M. Designation: A 87 – 27) which were accordingly discontinued in 1935.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

(*c*) *Full-annealing.*—The procedure for full annealing shall consist of allowing the castings to cool after pouring, to a temperature below the critical range; reheating to the proper temperature and for the required time as a preliminary procedure for the ultimate refinement of the grain; and cooling thereafter slowly in the furnace. The castings shall not be removed from the furnace until the pyrometer shows that the furnace charge has fallen uniformly to a temperature as low as 500 F. (260 C.).

(*d*) *Tempering or Drawing.*—When castings are tempered or drawn after being normalized or full annealed the temperature for tempering or drawing shall be below the critical range, but not less than 400 F. (204 C.).

(*e*) *Cooling.*—If agreed to by the purchaser, castings may be rapidly cooled by liquid quenching, liquid spraying, or air blasting, after full annealing or normalizing. After any such rapid cooling the castings shall be tempered or drawn at a temperature not less than 400 F. (204 C.), to relieve cooling stresses. Castings that are liquid quenched, excepting those of very simple light-section design, shall be removed from the quenching bath before they attain room temperature, and shall be placed in a furnace for tempering or drawing immediately following removal from the quenching bath.

(*f*) *Annealing Lugs.*—For the purpose of determining the quality of annealing, at least two and not more than four annealing lugs shall be cast on all castings weighing 150 lb. and over, also on such lighter castings as the purchaser or his inspector may require to be provided with such lugs. The locations of the annealing lugs shall be such that, when removed by the inspector, they shall indicate the effectiveness of the annealing treatment. The annealing lug shall be 1 in. in height, 1 in. in width, and $\frac{5}{8}$ in. in thickness where the lug joins the casting.

(*g*) *Reannealing.*—If, in the opinion of the inspector, a casting is not properly annealed, he may at his option require the casting to be reannealed.

Temperature Control

4. Furnace temperatures for heat treating shall be controlled effectively by pyrometers.

Chemical Composition

5. (*a*) Steel used for the castings shall conform to the following requirements as to chemical composition:

		GRADES A-1, A-2 AND B	GRADE C
Manganese, max., per cent		0.85	....
Phosphorus, max., per cent		0.05	0.05
Sulfur, max., per cent	Acid	0.06	0.06
	Basic	0.05	0.05

(*b*) Unless otherwise specified, the contents of carbon, silicon, and in the case of Grade C other alloying elements, shall be selected by the manufacturer to obtain the physical properties specified.

Ladle Analyses

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, sulfur and all other elements intentionally present in the steel. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot made during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5 (*a*), and to such additional requirements as may have been agreed upon between the purchaser and manufacturer.

Check Analysis

7. An analysis may be made by the purchaser from a broken tension test specimen or from a casting representing any melt. The chemical composition thus determined shall conform to the requirements specified in Section 5 (*a*) and to such additional requirements as may have been agreed upon between the purchaser and manufacturer. Drillings for analysis shall be taken at least ¼ in. beneath the surface, and in such manner as not to impair the usefulness of any casting selected for such check analysis.

Tension Tests

8. (*a*) Steel used for the castings shall conform to the following minimum requirements as to tensile properties,[1] determined from the required number of specimens having a 2-in. gage length, conforming to the dimensions shown in Fig. 1:

	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	REDUCTION OF AREA, PER CENT
Grade A-1 (Carbon steel)............	60 000	30 000	22	30
Grade A-2 (Carbon steel)............	60 000	30 000	26	38
Grade B (Carbon steel)..............	70 000	38 000	24	36
Grade C............................	90 000	55 000	22	40

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by an extensometer, at a crosshead speed not to exceed ⅛ in. per min. The tensile strength shall be determined at a speed of head not to exceed 1½ in. per min.

Test Specimens

9. Tension test specimens shall be machined by the manufacturer and shall conform to the dimensions shown in Fig. 1.

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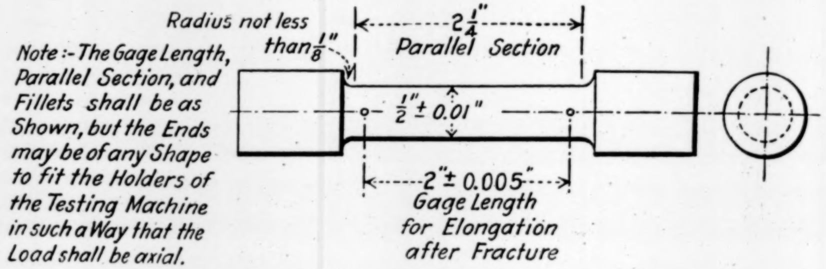
[1] Because it has come to the attention of Committee A-1 on Steel that the intent of tension test requirements in some specifications has at times been misinterpreted, the committee wishes to make it clear that it is not intended that a maximum limit shall be placed on any tensile property required in these specifications.

Number of Tests

10. (*a*) A sufficient number of test coupons from which the required test specimens may be prepared shall be cast attached near the end of each locomotive frame, to each locomotive cylinder, to each wheel center, and to each other casting weighing over 150 lb. each, except as otherwise specially provided for in these specifications. The test coupons shall remain attached to the castings throughout annealing and until the castings are presented for inspection. If the design of the casting is such that the test coupon cannot satisfactorily be attached to it, the coupon shall be attached to a runner connected with the casting. The locations of the test coupons and the method of casting them shall be subject to mutual agreement between the purchaser's inspector and the manufacturer. In the case of orders for castings weighing under 150 lb. each, the physical properties required in Section 8 (*a*) shall be determined from an extra or spare test coupon cast attached to another casting from the same melt.


Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) One tension test shall be made from a location near each end of every locomotive frame, and each such test shall conform to the requirements specified in Section 8 (*a*). One tension test may be made from each wheel center and each locomotive cylinder casting, and at least one tension test shall be made from one wheel center and one locomotive cylinder from each melt.

(*c*) One tension test shall be made for each melt represented by the castings covered by these specifications, with the exception of locomotive frames, wheel centers, and locomotive cylinders specially provided for in Paragraph (*b*) of this section; and with the further exception of lot-groupings specially provided for in Paragraph (*d*) of this section.

(*d*) *Consecutive Melts of Certain Castings.*—After the acceptance of 15 consecutive melts used for making castings other than locomotive frames, wheel centers, and cylinders, the manufacturer may, for application to all other castings, group succeeding melts in groups of five melts each, not exceeding 40 tons in weight per group. With the exceptions stated above, the castings in each such group shall be accepted if the chemical analyses and the test specimen representing the group fulfill the chemical and physical requirements of these specifications. If this test fails, a rehearing shall be granted for the melt represented by the failed specimen, and the four other melts of the group shall be tested individually.

(*e*) If a period of more than six months elapses between shipments of castings other than locomotive frames, wheel centers, and cylinders, each melt shall be tested individually until 15 of the consecutive melts have been accepted, as provided for in Paragraph (*d*) of this section; after which the melts may again be grouped.

(*f*) If one or more melts of a group provided for in Paragraph (*d*) of this section are rejected, each succeeding melt shall be tested individually until 15 consecutive melts have been accepted; after which the melts may again be grouped.

(*g*) *Small Orders.*—When either the purchaser's order, the available pattern equipment, or the foundry equipment is such that there cannot be cast in one melt more than five bolsters, truck sides, draft arms, yokes, or other castings of miscellaneous character weighing more than 150 lb. each, the physical properties specified in Section 8 (*a*) shall be determined from an extra or spare test coupon cast with or attached to another casting of the same melt.

(*h*) When insufficient coupons have been cast to cover the tension test requirements of these specifications, a test specimen may be cut from a finished casting at a location mutually agreed upon by the purchaser's inspector and the manufacturer, to cover any deficiency in the number of available coupons.

Retests

11. (*a*) If the results of the physical test for any lot[1] do not conform to the requirements specified, the manufacturer may re-anneal such lot, but not more than twice. The results of acceptable retests shall conform to the requirements specified in Section 8 (*a*).

(*b*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Alternative Tests to Destruction

12. When the purchaser's order covers castings weighing not more than 150 lb. each, a test to destruction may be substituted for the tension test, at the option of the purchaser's inspector. This test shall show the material to be ductile, free from injurious defects, and apparently suitable for the purpose intended.

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[1] The term "lot" as used in this paragraph means all castings from each melt in each heat-treatment charge.

Permissible Variations in Weight

13. The normal weights of castings shall have been previously agreed upon by the purchaser and the manufacturer. Shipment lots of castings shall not vary more than 5 per cent above nor more than 3 per cent below the weight agreed upon as normal for the affected casting.

Workmanship

14. All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started; or to the dimensions predicated by the pattern supplied by the purchaser, if no drawing has been provided.

Finish

15. (*a*) The castings shall be free from injurious defects, and shall be satisfactorily cleaned for their intended use when offered for inspection.

(*b*) Minor defects that will not ultimately impair the strength of the castings may, with the consent of the purchaser's inspector, be welded by an approved process. The defects shall first be cleaned out to solid metal, and after the castings are welded they shall be heat treated, if required by the purchaser's inspector.

Marking

16. The manufacturer's name or identification mark and the pattern number, also the purchaser's initials when specified, shall be cast on all castings. In addition, a serial number and other numbers indicating the month and year of manufacture shall be cast on all bolsters, truck side frames, wheel centers, cylinders, and similar castings. The locations and sizes of numbers shall be agreed upon by the manufacturer and the purchaser's inspector.

Inspection

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may, at his own expense, in his own laboratory or elsewhere, make tests to govern the acceptance or rejection of material ordered.

Rejection

18. (*a*) Material represented by samples which fail to conform to the requirements of these specifications shall be rejected.

(*b*) Material which shows injurious defects following original inspection and acceptance at the manufacturer's works shall be rejected. The manufacturer shall be notified promptly of such rejection.

Rehearing

19. Tested samples representing rejected material shall be held for 14 days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
CARBON-STEEL CASTINGS FOR MISCELLANEOUS INDUSTRIAL USES[1]

A.S.T.M. Designation: A 180 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover carbon-steel castings to be used for miscellaneous industrial purposes, as distinguished from carbon-steel castings made for railroad, marine, and high-temperature applications. Six grades of castings are covered: namely,

Grade N-1.—Castings not required to be physically tested, nor to be heat-treated except as conditionally provided for in Section 3.

Grade N-2.—Castings not required to be physically tested, but required to be annealed.

Grade A-1.—Castings of this grade as specified by the purchaser, required to be physically tested but not required to be heat treated except as conditionally provided for in Section 3.

Grade A-2.—Castings of this grade as specified by the purchaser, required to be annealed and to be physically tested.

Grade B.—Castings of this grade as specified by the purchaser, required to be annealed and to be physically tested.

Grade H.—Castings of this grade as specified by the purchaser, required to be annealed and to be physically tested.

Process

2. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter, or crucible.

Heat Treatment

3. (*a*) A heat treatment, either by normalizing or by full annealing, shall be applied to all castings of Grades N-2, A-2, B, and H, and to all

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

These specifications are in effect a tentative revision of, and will supersede when adopted as standard the present Standard Specifications for Carbon-Steel Castings (A.S.T.M. Designation: A 27 - 24), 1933 Book of A.S.T.M. Standards, Part I, p. 229.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

castings of Grades N-1 and A-1 when their carbon content exceeds 0.30 per cent (Note 1). Unless otherwise specified, all castings may be normalized or full annealed one or more times, and be given a supplementary heat treatment by tempering or drawing; all at the option of the manufacturer. At the option of the purchaser, castings so designated by him may be given a supplementary heat treatment that includes accelerated cooling by liquid quenching, liquid spraying, or air blasting (Note 2).

(*b*) All those castings that are to be heat treated in any manner shall have been allowed to cool after pouring, to a temperature below the critical range.

(*c*) *Normalizing.*—The procedure for normalizing shall consist of heating the castings to the proper temperature above the critical range for the required time as preliminary procedure for the ultimate refinement of the grain, and cooling in still air at room temperature (Note 3).

(*d*) *Full annealing.*—The procedure for full annealing shall consist of heating the castings to the proper temperature above the critical range for the required time as a preliminary procedure for the ultimate refinement of the grain, and cooling slowly in the furnace (Note 3). No casting so treated shall be removed from the furnace until the pyrometer indicates that the entire furnace charge has fallen to a temperature as low as 500 F. (260 C.).

(*e*) *Tempering or Drawing.*—The procedure for tempering or drawing shall consist of heating such castings as have been normalized or full annealed, or given an authorized accelerated cooling, to a temperature below the critical range but not less than 400 F. (204 C.), and cooling by a suitable method to obtain the desired results.

(*f*) *Cooling.*—The procedure for accelerated cooling by liquid quenching, liquid spraying, or air blasting shall follow heating the castings gradually to a suitable temperature (above or below the critical range), and holding at that temperature for the proper time to obtain the desired results. All castings that have been cooled by liquid contact or an air blast shall be tempered or drawn to relieve cooling stresses and/or strains, unless otherwise agreed to by the purchaser. With the exception of castings of very simple light section design, all liquid-quenched material shall be removed from the quenching bath before the castings attain room temperature, and shall be placed in the heat-treatment furnace for any required tempering or drawing immediately following removal from the quenching bath (Note 4).

NOTE 1.—According to current, officially accepted definitions, the term "heat treatment" covers any method of intentionally and systematically applying heat to a metal after it has cooled following pouring. Consequently the term now is used without regard to whether such heat is applied one or more times, and irrespective of the cooling procedure. The term "annealing" is authoritatively intended to cover either "normalizing" (air cooling) or "full annealing" (furnace cooling).

NOTE 2.—Accelerated cooling by liquid contact develops properties that are advantageous for certain purposes, when the details of steel casting design, of chemical composition, and of shop practice are suitable for liquid quenching or liquid spraying. The beneficial results obtainable by liquid quenching or liquid spraying include differential hardening, whereby some surfaces are made noticeably resistant to abrasion, while other portions of the castings retain more ductile and more easily machined properties.

NOTE 3.—The proper time for holding or "soaking" castings of moderate thickness at maximum temperature in the heat-treating furnace is believed by many persons to be one hour per inch of thickness of the heaviest member.

NOTE 4.—Usually the degree of hazard from cooling by liquid contact is estimated somewhat in proportion to the existing size and nearness to uniformity in member-thickness. Suitable equipment and technique employed for liquid quenching are important factors in obtaining desired results.

Temperature Control

4. Furnace temperatures for heat treating shall be controlled effectively by pyrometers.

Chemical Composition

5. Steel used for the castings shall conform to the following requirements as to chemical composition:

Manganese, max., per cent	1.00
Phosphorus, max., per cent	0.05
Sulfur, max., per cent	0.06

Ladle Analysis

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, silicon, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot made during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analysis

7. An analysis may be made by the purchaser from a broken tension test specimen or from a casting representing any melt. The chemical composition thus determined shall conform to the requirements specified in Section 5. Drillings for analysis shall be taken at least $\frac{1}{4}$ in. beneath the surface, and in such manner as not to impair the usefulness of any casting selected for such check analysis.

Tension Tests

8. (*a*) The tensile properties[1] of steel used for castings of the grades that require physical testing shall be determined from the required number of specimens having a 2-in. gage length, conforming to the dimensions shown in Fig. 1.

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[1] Because it has come to the attention of Committee A-1 on Steel that the intent of tension test requirements in some specifications has at times been misinterpreted, the committee wishes to make it clear that it is not intended that a maximum limit shall be placed on any tensile property required in these specifications.

(*b*) Unless otherwise specified or agreed to between the purchaser and the manufacturer, the tensile properties of the castings shall be determined from test coupons of any design selected by the manufacturer. One or more coupons, in the number required for the tension tests prescribed in these specifications, shall be cast separately on a specially designed test block or be cast attached to a commercial casting, in each melt used for manufacture of the castings purchased (Note 5). All test coupons may be cast separately unless otherwise specified or agreed to between the purchaser and the manufacturer. When a coupon is cast attached to a commercial casting, the manufacturer shall be permitted to select the location for the coupon and to provide for its attachment directly or by means of a runner connecting the commercial casting with the coupon or with a special block that may be needed for feeding the coupon. Test coupons shall be sufficient in size and number to provide the test specimens required.

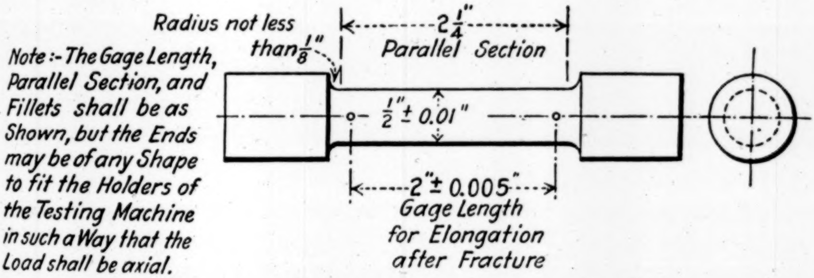
Radius not less than 1/8"
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*c*) When the suitability of tensile properties in the castings is based on the testing of specimens from coupons designed and cast as described in Paragraph (*b*) of this section, the minimum tensile requirements shall be as follows:

	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	REDUCTION OF AREA, PER CENT
Grade A-1, Unannealed (Note 6)	60 000	30 000	22	30
Grade A-2, Normalized or Full annealed (Note 6)	60 000	30 000	26	38
Grade B, Normalized or Full annealed (Note 6)	70 000	38 000	24	36
Grade H, Normalized or Full annealed (Note 6)	80 000	43 000	17	25

(*d*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by an extensometer, at a crosshead speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in per min.

NOTE 5.—The special test block conventionally used in many steel foundries, frequently called a "keel-block," consists of a slab or plate having a small area and one or more underlying ribs. The slab or upper portion is made sufficiently thick to properly feed the ribs or coupons, which often are approximately 1 in. thick. Specimens from coupons made uniformly in some such manner afford the only reliable means for making accurate comparative evaluations of steel used for casting manufacture.

Lower combinations of physical properties than those specified herein are obtained in testing specimens from coupons attached for their entire length directly to massive casting members formed under such conditions as to make the coupons cool very slowly. Greatly retarded initial cooling develops a larger granular structure than is found in coupons of the kind contemplated for the tension tests herein prescribed. This structure has an important influence on the physical properties of the steel as cast, and on the degree to which such properties may be affected by the heat treatment applied to the casting.

Higher combinations of physical properties than those specified herein are obtained in testing specimens from coupons on conventional test blocks, when the coupons are liquid quenched and subsequently tempered or drawn.

NOTE 6.—Grade B is used most extensively in making castings for miscellaneous industrial applications, and is easily machined with ordinary machine tools. Grades A-1 and A-2 are produced intentionally with such a low-carbon content as to make the material very soft and machineable with great ease, either in the "as-cast" or in the annealed condition. The carbon content adapts Grades A-1 and A-2 effectively for fusion fabrication with wrought parts of low-carbon steel. Grade H is used for purposes that call for higher strength and less required ductility than are typical of Grade B, and usually is machined without appreciable difficulty with modern tools.

Test Specimens

9. (*a*) Such physical test coupons as may have been connected directly or by runners to commercial castings (Section 8 (*b*)) shall remain so attached until the material is submitted for inspection. All physical test coupons shall be heat treated with the castings represented by them unless the purchaser authorizes separate heat treatment. Test coupons shall be provided by the manufacturer without extra charge in sufficient number to furnish specimens for all tests, except as otherwise agreed to between the purchaser and the manufacturer.

(*b*) If agreed to between the manufacturer and the purchaser's inspector, tension test specimens may be taken from commercial castings instead of from special coupons.

(*c*) Tension test specimens shall be machined by the manufacturer and shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests

10. (*a*) One tension test shall be made from each melt in each heat treatment charge.

(*b*) If any test specimen shows defective machining or develops flaws it may be discarded, in which case another specimen from the same lot[1] shall be substituted.

(*c*) After the acceptance (for one or more orders) of 15 consecutive melts containing castings subject to physical tests, the manufacturer may assemble the castings from succeeding melts in groups of five melts each, not exceeding 40 tons in weight per group. Each such group shall be accepted if the chemical analyses and the specimen representing the group fulfill the chemical and physical requirements of these specifications. If this test fails, a rehearing shall be granted for the melt represented by the failed specimen, and the four other melts of the group shall be tested individually.

Retests

11. (*a*) If the results of the physical test for any lot[1] do not conform to the requirements specified, the manufacturer may reheat treat such lot, but not more than twice. The results of acceptable retests shall conform to the requirements specified in Section 8 (*c*).

(*b*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Workmanship

12. All castings shall be made in a workmanlike manner and shall conform substantially to the dimensions on drawings furnished by the purchaser before manufacture is started; or to the dimensions predicated by the pattern supplied by the purchaser, if no drawing has been provided.

Finish

13. (*a*) The castings shall be free from injurious defects, and shall be satisfactorily cleaned for their intended use when offered for inspection.

(*b*) Minor defects that will not ultimately impair the strength of the castings may, with the consent of the purchaser's inspector, be welded by an approved process. The defects shall first be cleaned out to solid metal, and after the castings are welded they shall be heat treated, if required by the purchaser's inspector.

Marking

14. The manufacturer's name or identification mark and the pattern number, also the purchaser's identification marks when specified, shall be cast on all castings excepting those of such small size as to make such marking impracticable. In addition, the numbers of the melts used for pouring the castings shall be stamped on all castings individually weighing 300 lb. or more. The locations and sizes of cast identification marks shall be as agreed upon between the manufacturer and the purchaser's inspector (Note 7).

NOTE 7.—The resistance of a sand mold to the erosive effect of in-flowing metal is aided by smooth mold surfaces. Cast identification marks are formed by making indentations on the face of the mold. For the prevention of small defects caused by dislodged particles of molding sand there should be provided the minimum feasible number of cast identification marks.

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[1] The term "lot" as used in this paragraph means all castings from each melt in each heat-treatment charge.

Inspection

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects following original inspection and acceptance at the manufacturer's works shall be rejected. The manufacturer shall be notified promptly of such rejection.

Rehearing

17. Tested samples representing rejected material shall be held for 14 days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
FORGED OR ROLLED STEEL PIPE FLANGES FOR GENERAL SERVICE[1]

A.S.T.M. Designation: A 181 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. (*a*) These specifications cover forged or rolled steel flanges to be attached to piping or pressure vessels for general service. (See Explanatory Note).

(*b*) Two classes of material are covered, designated as Classes I and II, respectively. These materials are classified in accordance with their chemical and physical properties as specified in Sections 6 and 9 (*a*).

Certification of Test

2. Unless otherwise specified on the order, a certification that the material conforms to the requirements of these specifications shall be the basis of acceptance of the material.

Process

3. The steel may be made by either or both of the following processes: open-hearth or electric furnace.

Discard

4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Grain Flow

5. (*a*) Flanges shall be rolled or forged in a manner such that the grain flow shall be of a nature that is most favorable for resisting the stresses encountered in service.

(*b*) Flanges shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

Chemical Composition

6. The steel shall conform to the following requirements as to chemical composition:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935

	CLASS I	CLASS II
Carbon, max., per cent	0.35	[a]
Manganese, per cent	0.40 to 0.80	0.40 to 0.80
Phosphorus, max., per cent	0.05 [b]	0.05 [b]
Sulfur, max., per cent	0.05 [b]	0.05 [b]

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[a] The carbon content of Class II material shall be a matter of agreement between the purchaser and the manufacturer.

[b] See Section 8 (*a*).

Ladle Analysis

7. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 6.

Check Analysis

8. (*a*) An analysis may be made by the purchaser from one forged or rolled flange representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 6, except that the phosphorus and sulfur content may each be 0.055 per cent.

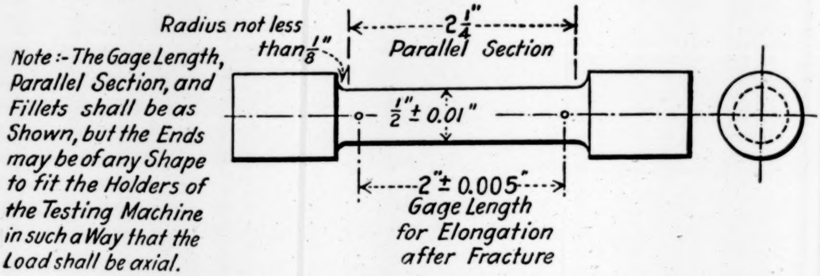
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) All drillings for analysis shall be taken at least $\frac{1}{4}$ in. below the surface, or turnings may be taken from tension test specimens.

Tension Tests

9. (*a*) Forged or rolled steel flanges shall conform to the following minimum requirements as to tensile properties:

	CLASS I	CLASS II
Tensile strength, lb. per sq. in.	60 000	70 000
Yield point, lb. per sq. in.	30 000	36 000
Elongation in 2 in., per cent	22.0	18.0
Reduction of area, per cent	35.0	24.0

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers, at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Tension Test Specimens

10. The tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

Number of Tests

11. (*a*) One tension test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any test specimen is less than that specified in Section 9 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*d*) For the purpose of making tension tests specified in Paragraph (*a*), the manufacturer shall supply suitable test specimens from the flange or at his option furnish test specimens cut from the billets or forging bar entering into the finished product, providing such test specimen has undergone approximately the same working and treatment as the finished product.

Retests

12. If any of the results of the physical tests for any melt do not conform to the requirements specified in Section 9 (*a*), a retest may be made on a specimen cut from a flange of the same melt furnished. This retest shall give results conforming to the requirements of Section 9 (*a*).

Workmanship

13. (*a*) The flanges shall conform to the sizes and shapes specified by the purchaser.

(*b*) The flanges shall be free from injurious defects and shall have a workmanlike finish.

Marking

14. Flanges shall be marked in accordance with the Product Marking System (No. SP-25-1934) of the Manufacturers Standardization Society of the Valves and Fittings Industry, and in such position as not to injure the usefulness of the flanges. In addition, they shall be marked with the Roman numeral I or II to designate the class of material as specified in Sections 6 and 9.

Inspection

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the flanges ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the flanges are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

16. (*a*) Unless otherwise specified, any rejection based on tests shall be reported within twelve working days from the receipt of samples.

(*b*) Flanges which show injurious defects while being finished shall be rejected.

Rehearing

17. Samples tested in accordance with Section 8, which represent rejected flanges, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTE

NOTE.—Reference may be made to the dimensional standards formulated by the Sectional Committee on Standardization of Pipe Flanges and Fittings under the procedure of the American Standards Association, A.S.A. Project B16 and more specifically to the American Standards for Steel Flanged Fittings and Companion Flanges, B16 *e*—1932. Copies of this American Standard are obtainable from the American Standards Association or from the American Society of Mechanical Engineers, 29 West 39th St., New York City.

TENTATIVE SPECIFICATIONS
FOR
ELECTRIC-RESISTANCE-WELDED STEEL AND OPEN-HEARTH IRON BOILER TUBES[1]

A.S.T.M. Designation: A 178 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover electric-resistance-welded tubes made of steel and open-hearth iron and intended for boiler tubes, boiler flues, superheater flues, safe ends (Note) and arch tubes.

NOTE.—Grade C tubes are not suitable for safe ending by forge welding.

Process

2. The material shall be made by either or both of the following processes: open-hearth or electric-furnace.

Heat Treatment

3. Electric-resistance-welded tubes shall be normalized at a temperature above the upper critical temperature.

Chemical Composition

4. The material shall conform to the following requirements as to chemical composition:

	GRADE A LOW-CARBON STEEL	GRADE B OPEN-HEARTH IRON	GRADE C MEDIUM-CARBON STEEL
Carbon, per cent................	0.08 to 0.18	0.03 max.	0.35 max.
Manganese, per cent............	0.30 to 0.60	0.03 max.	0.80 max.
Phosphorus, max., per cent......	0.04	0.02	0.04
Sulfur, max., per cent...........	0.045	0.045	0.045

Check Analyses

5. (*a*) Analyses of two tubes from each lot of 250 lengths or fraction thereof, and from each lot of 2000 ft. or fraction thereof of safe-end material may be made by the purchaser. Drillings for analysis shall be taken from several points around each tube selected for analysis. The chemical composition thus determined shall conform to the requirements specified in Section 4.

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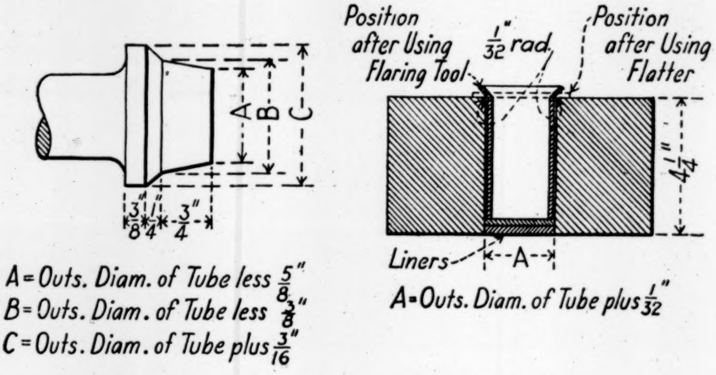
[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

(*b*) If the analysis of one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4.

Flange Tests

6. (*a*) For tubes not more than 6 in. in diameter and having a thickness not exceeding 10 per cent of their outside diameter, and providing the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen not less than 4 in. in length shall be capable of having a flange turned over at right angles to the body of the tube without cracking or showing any flaw. This flange, as measured from the outside of the tube, shall in no case be less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. Within these limits, the width of flange shall be not less than the following:


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Tube less 5/8"
B = Outs. Diam. of Tube less 3/8"
C = Outs. Diam. of Tube plus 3/16"
Position after Using Flaring Tool
1/32" rad.
Position after Using Flatter
4 1/4"
Liners
A
A = Outs. Diam. of Tube plus 1/32"

Flaring Tool

Die Block

FIG. 1.—Flaring Tool and Die Block for Flange Test.

OUTSIDE DIAMETER OF TUBE, IN.	WIDTH OF FLANGE	
	GRADES A AND B	GRADE C
Up to $2\frac{1}{2}$, incl.	15 per cent of outside diameter	75 per cent of that required for Grades A and B
Over $2\frac{1}{2}$ to $3\frac{3}{4}$, incl.	$\frac{3}{8}$ in.	
Over $3\frac{3}{4}$ to 6, incl.	10 per cent of outside diameter	

(*b*) For tubes other than specified in Paragraph (*a*) the flange test shall not be required.

(*c*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Flattening Tests

7. (*a*) For tubes, except Grade C, having a wall thickness not exceeding 10 per cent of their outside diameter, and providing the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen $2\frac{1}{2}$ in. in length shall stand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is three times the wall thickness.

(*b*) For tubes, except Grade C, other than specified in Paragraph (*a*), a test specimen 2½ in. in length shall stand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is four times the wall thickness.

(*c*) For Grade C tubes, a test specimen not less than 2½ in. in length shall be flattened between parallel plates with the weld at the point of maximum bending until opposite walls of the tube meet. No opening in the weld shall take place until the distance between the plates is less than two-thirds of the original outside diameter of the tube. No cracks or breaks in the metal elsewhere than in the weld shall occur until the distance between the plates is less than one-third of the original diameter of the tube. Evidence of laminations or burnt material shall not develop during the entire flattening process.

(*d*) All flattening tests shall be made with the weld at the point of maximum bend.

Crush Tests

8. When required by the inspector, crushing tests shall be made on test specimens 2½ in. in length which shall stand crushing longitudinally, without cracking, splitting or opening at the weld, as follows:

Grades A and B	No. 10 B.w.g. or lighter	to a height of ¾ in. or until outside folds are in contact
	Heavier than No. 10 B.w.g	to a height of 1¼ in.
Grade C		Crush tests not required for this grade

Tension Tests

9. (*a*) Grade C tubes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	60 000
Yield point, lb. per sq. in.	37 000
Elongation in 2 in., per cent	25

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by other approved method.

(*c*) Tension test specimens shall be cut longitudinally from the tube and not flattened between gage marks. The sides of the specimen shall be parallel between gage marks. If desired the test specimen may consist of a full section of the tube, except where the tube in full section exceeds the capacity of the testing machine.

Hydrostatic Tests

10. (*a*) Tubes under 5 in. in diameter shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in., and tubes 5 in. or over in diameter shall withstand an internal hydrostatic pressure of 800 lb. per sq. in., provided the fiber stress corresponding to these pressures does not exceed 16,000 lb. per sq. in. for Grades A and B, and 18,000 lb. per sq. in. for Grade C as determined by the following formula. Should the fiber stress

corresponding to these pressures exceed the above figures, the hydrostatic test pressure shall be determined by the following formula:

$$P = \frac{2St}{D}$$

where P = the hydrostatic test pressure in pounds per square in.
S = the allowable fiber stress of 16,000 lb. per sq. in. for Grades A and B tubes and 18,000 lb. per sq. in. for Grade C tubes
t = the thickness of tube wall in inches
D = the outside diameter of tube in inches

(*b*) Tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel-hand hammer or its equivalent.

Test Specimens

11. (*a*) Test specimens shall be taken from finished tubes. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested at room temperature.

Number of Tests

12. (*a*) For Grades A and B, one each of the tests specified in Sections 6, 7 and 8 shall be made on each of two tubes from each lot of 250 tubes or fraction thereof, and from each 2000 ft. or fraction thereof of safe-end material. For Grade C, one each of the tests specified in Sections 6, 7 (*c*) and 9 shall be made on each of two tubes from each lot of 250 tubes or fraction thereof.

(*b*) Each tube shall be subjected to the hydrostatic test specified in Section 10.

Retests

13. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 6, 7, 8 and 9, retests may be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If any tension test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

(*c*) If the elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Standard Weights

14. The standard weights for tubes of various outside diameters and thicknesses are given in Table I.

NOTE.—The weights given in Table I are theoretical and are based on tubes of the exact diameters and wall thicknesses shown. Minimum wall tubes, as called for in these specifications, will weigh not more than 15 per cent heavier than those shown, depending on the size and wall thickness specified.

Permissible Variations in Weights and Dimensions

15. (*a*) Variations in outside diameter, wall thickness, weight and length from those specified, shall not exceed the amounts shown in Table II.

(*b*) The diameter measured at any point on the outer circumference on finished tubes shall not vary more than the amounts shown in Table II.

Finish

16. Finished tubes shall be reasonably straight, free from injurious defects, shall have smooth ends, free from burrs, and shall have a workmanlike finish.

TABLE I.—STANDARD WEIGHTS OF ELECTRIC-RESISTANCE-WELDED BOILER TUBES.
INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES

Thickness		Weight, lb. per ft. of length								
		Outside Diameter, in.								
B.w.g.	In.	1	1¼	1½	1⅝	1¾	1⅞	2	2¼	2½
13	0.095	982	1.172	1.426	1.552	1.679	1.806	1.933	2.186	.....
12	0.109	...	.....	1.619	1.765	1.910	2.056	2.201	2.492	2.783
11	0.120	...	.....	1.769	1.929	2.089	2.249	2.409	2.730	3.050
10	0.134	...	.....	1.955	2.134	2.313	2.492	2.670	3.028	3.386
9	0.148	...	.....	2.137	2.335	2.532	2.730	2.927	3.323	3.718
8	0.165	...	.....	2.353	2.573	2.793	3.013	3.234	3.674	4.115
7	0.180	...	.....	.....	.....	.....	.....	3.499	3.979	4.460
6	0.203	...	.....	.....	.....	.....	.....	3.896	4.438	4.980
5	0.220	...	.....	.....	.....	.....	.....	4.182	4.770	5.357
4	0.238	...	.....	.....	.....	.....	.....	.....	.....	.....
3	0.259	...	.....	.....	.....	.....	.....	.....	.....	.....

Thickness		Weight, lb. per ft. of length							
		Outside Diameter, in.							
B.w.g.	In.	2¾	3	3¼	3½	3¾	4	4½	5
13	0.095	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	3.074	3.365	3.657	3.948	.....	.....	.....	.....
11	0.120	3.371	3.691	4.011	4.332	4.652	.....	.....	.....
10	0.134	3.744	4.102	4.459	4.817	5.175	5.533	6.248	6.964
9	0.148	4.113	4.508	4.903	5.298	5.693	6.089	6.879	7.669
8	0.165	4.555	4.996	5.436	5.877	6.317	6.758	7.639	8.520
7	0.180	4.941	5.421	5.901	6.382	6.863	7.344	8.305	9.266
6	0.203	5.522	6.064	6.606	7.148	7.690	8.232	9.316	10.40
5	0.220	5.944	6.538	7.119	7.707	8.294	8.881	10.05	11.23
4	0.238	.....	7.021	7.656	8.291	.....	.....	.....	.....
3	0.259	.....	7.582	8.273	8.965	.....	.....	.....	.....

Marking

17. (*a*) The name or brand of the manufacturer, the grade of material from which it is made, "Electric resistance welded" and whether steel or open-hearth iron, together with the hydrostatic pressure in pounds at which it was tested, shall be legibly stenciled on each tube 1¼ in. in outside diameter and over, provided the length is not under 3 ft.

(*b*) On tubes less than 1¼ in. in diameter and on all tubes under 3 ft. in length, the name, initials, or brand of the manufacturer, the grade and hydrostatic pressure in pounds at which it was tested shall be legibly stenciled or indicated on a sticker applied on each tube.

Inspection

18. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE II.—PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT OF ELECTRIC-RESISTANCE-WELDED BOILER TUBES.

Size, Outside Diameter	Outside Diameter (Including Out-of Roundness, in.		Wall Thickness, B.w.g.[a]		Weight per foot, per cent		Length, n.	
	Over	Under	Over	Under	Over	Under	Over	Under
4 in. and under	$\frac{1}{64}$	$\frac{1}{32}$	2	0	15	0	$\frac{3}{16}$	0
Over 4 in.	$\frac{1}{64}$	$\frac{3}{64}$	2	0	15	0	$\frac{3}{16}$	0

[a] The gaging tolerances given apply only to tubes as manufactured and before swaging and expanding.

(*b*) When inspection by the purchaser is waived, the manufacturer shall furnish, on request, a statement that the material has been tested and has met all the requirements of these specifications.

Rejection

19. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 (*a*) shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Tubes which fail in any of the above operations will be rejected, and the manufacturer shall be notified.

Rehearing

20. Samples tested in accordance with Section 5 (*a*) which represents rejected tubes, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS COLD-DRAWN STEEL HEAT-EXCHANGER AND CONDENSER TUBES[1]

(SIZES ½ IN. TO BUT NOT INCLUDING 2 IN. IN OUTSIDE DIAMETER)

A.S.T.M. Designation: A 179 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. (*a*) These specifications cover seamless low-carbon cold-drawn steel tubes (Note), for tubular heat exchangers, condensers and similar heat transfer apparatus, in sizes ½ in. to but not including 2 in. in outside diameter.

(*b*) Tubes shall be specified to two dimensions only, as follows: Outside diameter and minimum wall thickness, or outside diameter and average wall thickness.

NOTE.—The fundamental requirements of these specifications that is, kind and number of tests, dimensional tolerances, inspection, etc., are applicable to types of "low-alloy" steels intended to produce greater strength at elevated temperatures, but not intended specifically for corrosion resistance at elevated temperatures. When these specifications are applied to such steels, special requirements as to chemical composition and hardness will need to be substituted for those prescribed herein and such requirements shall be a matter of mutual agreement between the manufacturer and the purchaser.

Process

2. The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

Manufacture

3. (*a*) Tubes shall be made by the seamless process and shall be cold-drawn.

(*b*) Tubes shall be annealed to insure ductility.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition.

Carbon, per cent	0.08 to 0.18
Manganese, per cent	0.30 to 0.60
Phosphorus, max. per cent	0.04
Sulfur, max. per cent	0.045

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Check Analysis

5. (*a*) When requested by the purchaser, analyses of two tubes from each lot of 250 tubes or fraction thereof shall be made. Drillings for analysis shall be taken from several points around each tube selected for analysis. The chemical composition thus determined shall conform to the requirements specified in Section 4.

(*b*) If the analysis of one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4.

Flattening Tests

6. (*a*) For tubes having wall thicknesses[1] not exceeding 10 per cent of their outside diameters a section not less than 2½ in. in length shall stand being flattened between parallel plates until the distance between the plates is three times the wall thickness, without cracking or showing flaws.

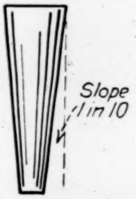

FIG. 1.—Tapered Mandrel for Flaring Test.

(*b*) For tubes having wall thicknesses[1] exceeding 10 per cent of their outside diameters a section not less than 2½ in. in length shall stand being flattened between parallel plates until the distance between the plates is four times the wall thickness, without cracking or showing flaws.

Flaring Test[2]

7. (*a*) A section of tube approximately 4 in. in length shall stand being expanded over a tapered mandrel having a slope of 1 in 10 (Fig. 1) until the inside diameter at one end is increased 20 per cent, without cracking or showing flaws.

(*b*) *Alternative Flange Test.*—For tubes having wall thicknesses[1] less than 10 per cent of the outside diameter, when specified on the order, a flange test may be substituted for the flaring test prescribed in Paragraph (*a*), in which case a test specimen not less than 4 in. in length shall be capable of having a flange turned over at right angles to the body of the tube without cracking or showing flaws. This flange as measured from the outside of the tube shall not be less than $\frac{1}{8}$ in. nor more than $\frac{3}{8}$ in. Within these limits, the width of the flange shall not be less than 15 per cent of the outside of the tube.

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[1] The term "wall thickness" shall be defined as the actual "mean" wall of the material tested.

[2] In determining the ratio of inside diameter to outside diameter the inside diameter shall be defined as the actual "mean inside diameter" of the material tested.

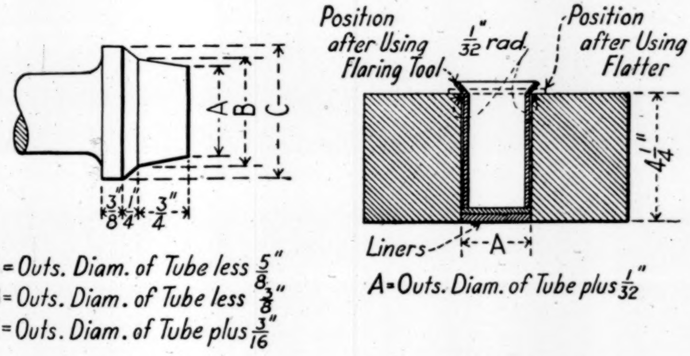
(*c*) For tubes heavier than specified in Paragraph (*b*) the flange test shall not be required.

(*d*) In making the flange test it is recommended that the flaring tool and die block shown in Fig. 2 be used.

Hardness Test

8. (*a*) A Rockwell test shall show a hardness number not to exceed 65 B Scale.

(*b*) The hardness test may be made on the tube near the end or on a specimen cut from the tube, at the option of the manufacturer.


Position after Using Flaring Tool
1/32" rad.
Position after Using Flatter
A
B
C
3/8"
1/4"
3/4"
4 1/4"
Liners
A
A = Outs. Diam. of Tube less 5/8"
B = Outs. Diam. of Tube less 3/8"
C = Outs. Diam. of Tube plus 3/16"
A = Outs. Diam. of Tube plus 1/32"

Flaring Tool Die Block

FIG. 2.—Flaring Tool and Die Block for Flange Test.

(*c*) In making the Rockwell hardness tests reference should be made to the Tentative Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18 – 33 T) of the American Society for Testing Materials.[1]

Hydrostatic Test

9. Each tube shall be tested at the mill and shall withstand a hydrostatic pressure of 1000 lb. per sq. in.

Test Specimens

10. (*a*) Test specimens shall be taken from the ends of finished tubes before being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) All specimens shall be tested at room temperature.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 967 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1377.

Number of Tests

11. (*a*) One flattening and one flaring or flange test specified in Sections 6 and 7 shall be made on each of two tubes from each lot of 250 tubes or fraction thereof.

(*b*) Five per cent of all tubes shall be selected for the hardness test specified in Section 8 and one Rockwell hardness determination shall be made on each of these tubes.

(*c*) Each tube shall be subjected to the hydrostatic test specified in Section 9.

Table I.—Permissible Variations in Dimensions of Tubes.

Size, Outside Diameter, in.	Outside Diameter (Including Out of Roundness), in.		Inside Diameter,[a] in.		Wall Thickness,[a] per cent		Cut Length, in.	
	Over	Under	Over	Under	Over	Under	Over	Under
Permissible Variations for Average Wall Tubes								
Under 1	0.004	0.004	0.004	0.004	10	10	$\frac{1}{8}$	0
1 to $1\frac{1}{2}$, incl	0.006	0.006	0.006	0.006	10	10	$\frac{1}{8}$	0
Over $1\frac{1}{2}$ to 2, excl	0.008	0.008	0.008	0.008	10	10	$\frac{1}{8}$	0
Permissible Variations for Minimum Wall Tubes								
Under 1	0.004	0.004	.....	.....	22	0	$\frac{1}{8}$	0
1 to $1\frac{1}{2}$, incl	0.006	0.006	.....	.....	22	0	$\frac{1}{8}$	0
Over $1\frac{1}{2}$ to 2, excl	0.008	0.008	.....	.....	22	0	$\frac{1}{8}$	0

[a] For tubes having an inside diameter less than 60 per cent of the outside diameter or having a wall $\frac{3}{4}$ in. or over in thickness, which cannot be successfully drawn over a mandrel, the inside diameter may vary over or under by an amount equal to 10 per cent of the wall thickness. The wall thickness of these tubes may vary $12\frac{1}{2}$ per cent over or under that specified.

For tubes having an inside diameter less than $\frac{1}{2}$ in., which cannot be successfully drawn over a mandrel, the wall thickness may vary 15 per cent over or under that specified; and the inside diameter will be governed by the outside diameter and wall thickness variations.

Note.—While the tubes are actually made to cold-drawn mechanical tubing tolerances the additional tolerances shown in Table I are required on account of warping caused by annealing and straightening.

Retests

12. (*a*) If the results of the physical tests of any lot do not conform to the requirements specified in Sections 6, 7, and 8, retests may be made on additional tubes of double the original number from that lot, each of which shall conform to the requirements specified.

(*b*) If a lot fails to meet the requirements of Sections 6, 7, and 8, that lot may be retreated and resubmitted for test.

Permissible Variations in Dimensions

13. Variations in diameter, wall thickness, and length from those specified, shall not exceed the amounts shown in Table I.

Finish

14. Finished tubes shall be reasonably straight and have smooth ends free from burrs. They shall be free from scale and injurious defects and shall have a workmanlike finish. A slight amount of oxidation will not be considered as scale.

Marking

15. The name or brand of the manufacturer, grade and hydrostatic pressure in pounds at which they were tested shall be indicated on a tag securely attached to the bundle or box in which the tubes are shipped.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

(*b*) When inspection by the purchaser is waived, the manufacturer shall furnish, on request, a statement that the material has been tested and has met all the requirements of these specifications.

Rejection

17. (*a*) When inspection at the place of manufacture has been waived, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from receipt of samples.

(*b*) Tubes which fail in the process of installation shall be set aside and the manufacturer notified.

Rehearing

18. When inspection at place of manufacture has been waived, samples tested in accordance with Section 5, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS LOW-CARBON-STEEL STILL TUBES FOR REFINERY SERVICE[1]

A.S.T.M. Designation: A 161 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These specifications cover seamless hot-rolled and cold-drawn low-carbon-steel still tubes (Note) for carrying oil at elevated temperatures and pressures in various types of oil stills in which the tubes may be subjected to a furnace temperature higher than that of the contained fluid, in sizes 2 in. in outside diameter or larger and of heavier than No. 5 B.w.g. minimum or $\frac{1}{4}$ in. average wall thickness.

(*b*) Tubes shall be specified to two dimensions only; the outside diameter and minimum wall thickness, or outside diameter and average wall thickness.

NOTE.—The fundamental requirements of these specifications, that is, kind and number of tests, dimensional and weight tolerances, inspection, etc., are applicable to types of "low-alloy" steels intended to produce greater strength at elevated temperatures, but not intended specifically for corrosion resistance at elevated temperatures. When these specifications are applied to such steels, special requirements as to chemical composition and suitable physical properties will need to be substituted for those prescribed herein and such requirements shall be a matter of mutual agreement between the manufacturer and the purchaser. When this type of material is ordered with 0.45 to 0.65 per cent molybdenum, the maximum Brinell hardness should be raised to 150, and the elongation in 2 in. reduced to 30 per cent.

Process

2. The steel shall be a killed steel and shall be made by either or both of the following processes: open-hearth or electric-furnace.

Manufacture

3. (*a*) Tubes shall be made by the seamless process and shall be either hot-rolled or cold-drawn, as specified.

(*b*) Cold-drawn tubes shall be annealed "dead soft" after the final cold-draw pass. Hot-rolled tubes need not be annealed.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

Chemical Composition

4. (*a*) The steel shall conform to the following requirements as to chemical composition:

Carbon, per cent	0.10 to 0.20
Manganese, per cent	0.30 to 0.60
Phosphorus, max., per cent	0.04
Sulfur, max., per cent	0.045
Silicon, max., per cent	0.25

(*b*) When requested by the purchaser, the manufacturer shall submit a report of the ladle analysis of each melt of steel from which the tubes have been made.

Check Analysis

5. (*a*) Analyses of two tubes from each lot of 100 tubes or fraction thereof shall be made. The chemical composition thus determined shall conform to the requirements specified in Section 4 (*a*). Drillings for analysis shall be taken from several points around each tube selected for analysis.

(*b*) If the analysis of one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified in Section 4 (*a*).

Tension Tests

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, min., lb. per sq. in.	47 000
Yield point, min., lb. per sq. in.	26 000
Elongation in 2 in., min., per cent	35

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or other approved method.

(*c*) Longitudinal tension tests, if practicable, may be made on full sections of the tubes up to the capacity of the testing machines. For larger size tubes, the tension specimens shall consist of a strip cut longitudinally from the tube and not flattened between gage marks. The sides of the specimen shall be parallel between gage marks; the width, irrespective of thickness up to and including $\frac{3}{4}$ in. shall be 1 in. and the gage length shall be 2 in. When the wall thickness exceeds $\frac{3}{4}$ in. the standard A.S.T.M. $\frac{1}{2}$-in. round tension test specimen may be used.

Flattening Test

7. (*a*) For tubes having wall thicknesses[1] not exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand

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[1] The term "wall thickness" shall be defined as the actual "mean" wall of the material tested. (See Notes 1 and 2.)

being flattened between parallel plates until the distance between the plates is three times the wall thickness, without cracking or showing flaws.

(*b*) For tubes having wall thickness exceeding 10 per cent of their outside diameters, a section not less than $2\frac{1}{2}$ in. in length shall stand being flattened between parallel plates until the distance between the plates is four times the wall thickness, without cracking or showing flaws.

(*c*) All flattening tests shall be made on the tube as rolled or drawn, prior to upsetting.

Flaring Test

8. (*a*) A section of the tube approximately 4 in. in length shall stand being flared with a tool having a 60-deg. included angle until the tube at the mouth of the flare has been expanded to the following percentages, without cracking or showing flaws:

RATIO OF INSIDE DIAMETER TO OUTSIDE DIAMETER[a]	MINIMUM EXPANSION OF INSIDE DIAMETER, PER CENT
0.9	20
0.8	22
0.7	25
0.6	30
0.5	37
0.4	50
0.3	67

[a] In determining the ratio of inside diameter to outside diameter, the inside diameter shall be defined as the actual "mean inside diameter" of the material tested. (See Notes 1 and 2).

(*b*) All flaring tests shall be made on the tube as rolled or drawn, prior to upsetting.

Hardness Test

9. (*a*) A Brinell test shall show a hardness number not to exceed the following:

	BRINELL HARDNESS NUMBER
For hot-rolled tubes	137
For cold-drawn tubes	125

(*b*) The hardness test may be made on the tube near the end or on a specimen cut from the tube, at the option of the manufacturer.

(*c*) In making the Brinell hardness test, reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Hydrostatic Test

10. (*a*) Each tube shall be tested at the mill to a hydrostatic pressure which shall be determined by the following formula:

$$P = \frac{32{,}000\, t}{D}$$

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

where P = the hydrostatic test pressure in pounds per square inch
t = the thickness of tube wall in inches
D = the outside diameter of tube in inches

(*b*) The maximum test pressure shall not exceed 2500 lb. per sq. in. for sizes 3 in. or under in outside diameter, nor 4500 lb. per sq. in. for sizes over 3 in. in outside diameter.

Test Specimens

11. (*a*) Test specimens shall be taken from the ends of finished tubes before being cut to length. They shall be smooth on the ends and free from burrs and flaws.

(*b*) All specimens shall be tested at room temperature.

Table I.—Permissible Variations in Dimensions and Weight of Still Tubes.

Size	Permissible Variations											
	Outside Diameter, in.		Cut Length, in.		When Wall Thickness is Specified as "Minimum"				When Wall Thickness is Specified as "Average"			
Outside Diameter, in.					Specified Wall Thickness, per cent		Calculated Weight per Foot, per cent		Specified Wall Thickness, per cent		Theoretical Weight per Foot, per cent	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Hot-Rolled Still Tubes												
4 or under..........	$\frac{1}{64}$	$\frac{1}{32}$	$\frac{3}{16}$	0	28	0	$3\frac{1}{2}$	5	$12\frac{1}{2}$	$12\frac{1}{2}$	$3\frac{1}{2}$	5
Over 4 to $7\frac{1}{2}$, inclusive	$\frac{1}{64}$	$\frac{3}{64}$	$\frac{3}{16}$	0	28	0	$3\frac{1}{2}$	5	$12\frac{1}{2}$	$12\frac{1}{2}$	$3\frac{1}{2}$	5
Cold-Drawn Still Tubes[a]												
4 or under..........	0.015	0.015	$\frac{3}{16}$	0	22	0	$3\frac{1}{2}$	5	10	10	$3\frac{1}{2}$	5
Over 4 to $7\frac{1}{2}$, inclusive	0.015	0.025	$\frac{3}{16}$	0	22	0	$3\frac{1}{2}$	5	10	10	$3\frac{1}{2}$	5

[a] When cold-drawn tubes as ordered require wall thicknesses $\frac{3}{4}$ in. or over, or an inside diameter 60 per cent or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shown in the upper table shall apply.

Number of Tests

12. (*a*) One tension, one flattening and one flaring test, specified in Sections 6, 7 and 8, shall be made on each of two tubes from each lot of 100 tubes or fraction thereof.

(*b*) Five per cent of all tubes shall be selected for the hardness test, specified in Section 9, and one Brinell determination shall be made on each of these tubes.

(*c*) Each tube shall be subjected to the hydrostatic test specified in Section 10.

Retests

13. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 6, 7, 8 and 9, retests may be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

(*b*) If any tension test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

TABLE II.—PLUG GAGE DIMENSIONS FOR TUBES WITH PLAIN ENDS.

A plug gage 4 in. in length, with a diameter determined by the proper formula given in this table shall enter each end of each tube for a distance of 4 in.

	Outside Diameter, in.	Hot-Rolled Still Tubes	Cold-Drawn Still Tubes
		Formulas[a]	Formulas[a]
When wall thickness is specified as "Minimum"	4 or under	$PG=D-\frac{2t}{0.875}-0.077$	$PG=D-\frac{2t}{0.90}-0.0625$
	Over 4 to $7\frac{1}{2}$, inclusive	$PG=D-\frac{2t}{0.875}-0.102$	$PG=D-\frac{2t}{0.90}-0.080$
When wall thickness is specified as "Average"	4 or under	$PG=D-2t-0.077$	$PG=D-2t-0.0625$
	Over 4 to $7\frac{1}{2}$, inclusive	$PG=D-2t-0.102$	$PG=D-2t-0.080$

[a] Expressions used in formulas are as follows:
PG = the diameter of plug gage in inches
D = the specified outside diameter of tube in inches
t = the specified thickness of tube wall in inches

TABLE III.—PLUG GAGE DIMENSIONS FOR TUBES WITH INTERNAL UPSET ENDS.

For tubes which are upset at the ends, a plug gage with a diameter determined by the proper formula given in this table shall enter the upset ends of each tube for a distance equal to the length of the upset.

Length of Upset, in.	Hot-Rolled Still Tubes		Cold-Drawn Still Tubes	
	Formulas[a]		Formulas[a]	
	Minimum Wall	Average Wall	Minimum Wall	Average Wall
3 or under	$PG=D-2\left(\frac{t}{0.875}+U\right)-0.093$	$PG=D-2(t+U)-0.093$	$PG=D-2\left(\frac{t}{0.90}+U\right)-0.093$	$PG=D-2(t+U)-0.093$
Over 3 to 4, inclusive	$PG=D-2\left(\frac{t}{0.875}+U\right)-0.113$	$PG=D-2(t+U)-0.113$	$PG=D-2\left(\frac{t}{0.90}+U\right)-0.113$	$PG=D-2(t+U)-0.113$
Over 4 to 5, inclusive	$PG=D-2\left(\frac{t}{0.875}+U\right)-0.133$	$PG=D-2(t+U)-0.133$	$PG=D-2\left(\frac{t}{0.90}+U\right)-0.133$	$PG=D-2(t+U)-0.133$

[a] Expressions used in formulas are as follows:
PG = the diameter of plug gage in inches
D = the specified outside diameter of tube in inches
t = the specified thickness of tube wall in inches
U = the increase in tube wall thickness at upset end in inches

(*c*) If the elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Permissible Variations in Dimensions and Weight

14. (*a*) Variations in diameter, wall thickness, weight and length from those specified, shall not exceed the amounts shown in Tables I to III. (See Notes 1 and 2.)

(*b*) If requested by the purchaser, 10 per cent of the finished tubes may be weighed individually or in convenient lots.

(*c*) Tubes shall be of such diameter that a ring gage approximately 1 in. in length with a bore 0.025 in. larger than the specified outside diameter will pass over each end for a distance of 8 in. This tolerance applies also to the ends of upset tubes.

(*d*) Permissible variations for hot-finished tubes shall apply to the upset ends of both hot-finished and cold-drawn tubes.

Finish

15. (*a*) Finished tubes shall be reasonably straight and have smooth ends, free from burrs. They shall be free from injurious defects and have a workmanlike finish. Minor defects may be removed by grinding, provided the wall thickness is not decreased to less than that permitted in Section 14.

(*b*) The normal rotary straightening operation shall be deemed sufficient to remove scale for inspection.

Marking

16. Tubes shall be marked by paint stenciling with the manufacturer's name (or stamped with his private identifying mark, when specified), grade, name and order number of purchaser, size and hydrostatic test pressure, and whether hot-rolled or cold-drawn.

Inspection

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, inspection and all tests shall be made at the place of manufacture.

(*b*) When inspection by the purchaser is waived, the manufacturer shall furnish, on request, a statement that the material has been tested and has met all the requirements of these specifications.

Rejection

18. (*a*) When inspection at the place of manufacture has been waived, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from receipt of samples.

(*b*) Tubes which fail in the process of installation shall be set aside and the manufacturer notified.

Rehearing

19. When inspection at place of manufacture has been waived, samples tested in accordance with Section 5, which represent rejected tubes, shall

be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTES

NOTE 1: *Average Wall.*—When an average wall tube is specified, the theoretical weight per foot of the tube is based on the exact specified dimensions. The actual wall thickness may vary over or under the specified thickness by certain definite amounts.

For the theoretical weight: $W = (D - t)t\ 10.68$

For the nominal inside diameter: $ID = D - 2t$

where W = the weight per foot of tube in pounds
ID = the inside diameter of tube in inches
D = the specified outside diameter of tube in inches
t = the specified wall thickness of tube in inches
10.68 = the weight constant

The actual weight of finished tubes may vary 5 per cent under or $3\frac{1}{2}$ per cent over the theoretical weight.

NOTE 2: *Minimum Wall.*—When a minimum wall tube is specified, the wall thickness shall at no point be less than that specified, but may exceed that thickness by a certain definite amount. This necessitates establishing a "mean" wall dimension between the maximum and minimum dimensions.

For hot-finished tubes the "mean" wall thickness $= \dfrac{\text{specified wall thickness}}{0.875}$

For cold-drawn tubes the "mean" wall thickness $= \dfrac{\text{specified wall thickness}}{0.90}$

Since the wall thickness of the tube has now been increased it follows that the weight per foot has been increased also.

The weight may be determined by the following formulas:

For hot-finished tubes: $W = \left(D - \dfrac{t}{0.875}\right)\dfrac{t}{0.875}\ 10.68$

For cold-drawn tubes: $W = \left(D - \dfrac{t}{0.90}\right)\dfrac{t}{0.90}\ 10.68$

The actual weight of finished tubes may vary 5 per cent under or $3\frac{1}{2}$ per cent over this calculated weight.

The nominal inside diameters of minimum wall tubes may be determined from the following formulas:

For hot-finished tubes: $ID = D - 2\dfrac{t}{0.875}$

For cold-drawn tubes: $ID = D - 2\dfrac{t}{0.90}$

where W = the weight per foot in pounds
ID = the nominal inside diameter of tube in inches
D = the specified outside diameter of tube in inches
t = the specified wall thickness of tube in inches

TENTATIVE SPECIFICATIONS

FOR

ALLOY-STEEL CASTINGS FOR VALVES, FLANGES AND FITTINGS FOR SERVICE AT TEMPERATURES FROM 750 TO 1100 F.[1]

A.S.T.M. Designation: A 157 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1934; Revised, 1935.[2]

Scope

1. (*a*) These specifications cover alloy-steel castings for valves, pipe flanges and pipe fittings, intended for service at metal temperatures from 750 to 1100 F. (Note 1).

(*b*) Eight grades of materials are included, six ferritic steels and two austenitic steels designated C 1, C 2, etc., which are classified in accordance with their chemical and physical properties as specified in Sections 5 and 8. Selection will depend upon design and service conditions, physical properties, and the high-temperature characteristics (Note 2).

Process

2. Steels C 1, C 2, C 4, C 5 and C 11 shall be made by the open-hearth, crucible or electric-furnace process. Steels C 6, C 9 and C 10 shall be made by the electric-furnace or crucible process.

Heat Treatment Required

3. (*a*) All castings shall receive heat treatment suitable to their design and chemical composition. Heat treatment shall be performed before machining except in instances when reheat treating is necessary. Unless the method of heat treatment is specified by the purchaser, thus becoming a matter of agreement with the manufacturer, the type of heat treatment used shall be at the option of the manufacturer. This latter condition must necessarily apply to castings for stock purposes.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Revision accepted by Committee E-10 on Standards, August 22, 1935.

(*b*) The ferritic steels C 1, C 2, C 4, C 5, C 6 and C 11 may be fully annealed, or fully annealed and drawn, or normalized and drawn, or annealed and normalized and drawn, or normalized and annealed.

(*c*) The austenitic steels C 9 and C 10 shall receive a stabilizing treatment as described in Section 4 (*d*).

Heat Treatment

4. (*a*) *Full Annealing.*—The procedure for full annealing shall consist in allowing the castings to cool after pouring, to a temperature below the critical range, reheating to the proper temperature and for the required time to refine the grain, and cooling thereafter slowly in the furnace. The castings shall not be removed from the furnace until the pyrometer shows that the furnace has fallen to a temperature below 500 F. (260 C.).

(*b*) *Normalizing.*—The procedure for normalizing shall consist in allowing the castings to cool after pouring, to a temperature below the critical range, reheating to the proper temperature and for the required time to refine the grain, and cooling in still air at room temperature.

(*c*) *Drawing or Tempering.*—The procedure for drawing, or tempering, shall consist in reheating the castings to a temperature at least 150 F. (85 C.) above the temperature to be encountered in service, and holding at that temperature not less than one and one-half hours per inch or less of wall thickness, followed by cooling in the furnace or in still air. When castings are used for service at temperatures under 750 F., the minimum draw temperature shall be 800 F.

(*d*) *Stabilizing Treatment.*—The procedure for stabilizing austenitic steels shall consist in heating to the proper stabilizing temperature and holding at that temperature for sufficient time, followed by rapid air cooling or by quenching in a liquid medium.

(*e*) *Temperature Regulation.*—Furnace temperatures shall be effectively regulated by means of pyrometers.

Chemical Composition[1]

5. Each alloy[2] shall conform to the following chemical requirements, or to other chemical requirements as specified in the purchase order:

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

[2] Alloys have been numbered so that similar alloys in the corresponding specifications for pipe, forgings, and bolting will bear the same number for alloys numbered 10 or below. No alloys C 3, C 7, C 8 or C 12 are included herein as the particular compositions corresponding to these numbers are not included in these specifications.

Class	Ferritic Steels						Austenitic Steels	
Grade	C 1	C 2	C 11	C 4	C 5	C 6	C 9	C 10
	Carbon-Molybdenum	Manganese-Molybdenum	Nickel-Chromium	Nickel-Chromium-Molybdenum	4 to 6 per cent Chromium	13 per cent Chromium	18 per cent Chromium, 8 per cent Nickel	20 per cent Nickel, 8 per cent Chromium
Carbon, per cent	0.45 max.	0.35 max.	0.45 max.	0.45 max.	0.15 to 0.35	0.15 max.	0.15 max.	0.35 max.
Manganese, per cent	1.00 max.	1.00 to 1.60	1.00 max.	1.00 max.	1.00 max.	1.00 max.	1.00 max.	1.50 max.
Phosphorus, per cent	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Sulfur, per cent	0.06 max.	0.06 max.	0.06 max.	0.06 max.	0.06 max.	0.05 max.	0.05 max.	0.05 max.
Silicon, per cent	0.20 min.	0.20 min.	0.20 min.	0.20 min.	0.20 min.	1.00 max.	2.00 max.	2.00 max.
Nickel, per cent	......	....	1.00 to 2.25	0.75 to 1.50	....	0.80 max.	8.00 to 10.30	19.0 to 22.0
Chromium, per cent	......	....	0.50 to 1.00	0.50 to 1.00	4.00 to 6.50	11.5 to 13.5	17.5 to 20.0	7.00 to 9.00
Molybdenum, per cent	0.40 min.	0.20 min.	0.20 to 0.40[a]	0.30 to 0.60	0.40 to 0.65[b]	0.50 max.	As agreed upon	......
Tungsten, per cent	......	....	0.40 to 0.80[a]	......	0.80 to 1.25[b]	......	....	......

[a] Either molybdenum or tungsten may be used, if desired.
[b] Either molybdenum or tungsten shall be used.

Ladle Analysis

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of the elements specified in Section 5. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analysis

7. Analysis may be made by the purchaser from castings or from broken test specimens, representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 5.

Tension Tests

8. (*a*) The castings shall conform to the following minimum requirements as to tensile properties[1] at room temperature:

	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	REDUCTION OF AREA, PER CENT
Grade C 1	80 000	50 000	22.0	45.0
Grade C 2	90 000	60 000	22.0	45.0
Grade C 11	100 000	65 000	18.0	30.0
Grade C 4	100 000	65 000	18.0	30.0
Grade C 5	100 000	65 000	18.0	30.0
Grade C 6	85 000	55 000	20.0	40.0
Grade C 9	70 000	30 000	35.0	40.0
Grade C 10	65 000	30 000	30.0	35.0

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

(*b*) Tension tests at room temperature shall be made by the manufacturer from each melt in each heat-treatment charge. Such tests may be witnessed by the purchaser or his representative, or reported to him, as may be specified in the order. The results of these tests shall conform to the minimum tensile properties specified in Paragraph (*a*). Authentic test records of tests made during manufacture of stock valves shall be accepted in lieu of witness tests.

(*c*) The yield strength shall correspond to a limiting permanent set of 0.2 per cent of the gage length of the specimen. The "set method" of determining yield strength as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[1] shall be followed. The tensile strength shall be determined at a cross-head speed of not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

9. (*a*) Bend tests shall be required for castings only when so specified in the purchase order.

(*b*) When a bend test is specified, the test specimens shall stand being bent cold through an angle of 90 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

Test Specimens

10. (*a*) For castings having a net weight of not over 500 lb., tension test specimens, and, when a bend test is specified, bend test specimens, shall be taken from test bars attached to special blocks. For castings over 500 lb., net weight, the test specimens shall be taken from test bars cast attached to the castings where practicable. If, as agreed upon between the manufacturer and purchaser, the design of the castings is such that test bars attached directly to the castings might injuriously affect the latter or the test specimen, the test bars shall be cast attached to special blocks. Test bars from which tension test specimens are to be taken shall remain attached to the castings or blocks they represent until submitted for inspection, and shall be heat-treated with the castings, unless the purchaser authorizes detachment before treatment. Test bars shall be provided by the manufacturer in sufficient number to furnish all tests required by these specifications or as agreed upon.

(*b*) Tension test specimens shall be machined and shall be of the usual type for 2-in. gage length as described in Section 15 of the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

The diameter of the test specimen shall be 0.505 in. The ends shall be of such form to fit the holder of the testing machine in such a way that the load shall be axial.

Number of Tests

11. One tension test and, when specified, one bend test shall be made from each melt in each heat-treatment charge, and, when specified in the inquiry, from each casting weighing 500 lb. or over.

Retests

12. (*a*) If the results of the tension tests for any lot do not conform to the requirements specified in Section 8 (*a*), such lot may be heat treated again, but not more than twice. Retests shall be made as specified in Section 11.

(*b*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 (*a*), and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case another specimen from the same melt and heat treatment charge shall be substituted.

Hydrostatic Tests

13. Each casting shall be tested after machining to the hydrostatic pressure specified in the following table and shall show no leaks. Castings ordered under these specifications, for working pressures other than those listed below, shall be tested to such pressures as may be agreed upon by the manufacturer and purchaser:

PRIMARY SERVICE PRESSURE RATING AT 750 F., LB. PER SQ. IN.	STANDARD HYDROSTATIC TEST PRESSURE, LB. PER SQ. IN.
100	350
300	750
400	1000
600	1500
900	2000
1500	3500

Radiographic or Destruction Tests

14. (*a*) When so specified in the purchase order, the purchaser may, at his own expense, examine the castings for internal defects by means of X-ray or gamma-rays of radium, and castings showing injurious defects shall be rejected.

(*b*) Or when so specified in the purchase order, the purchaser may, at his own expense, select representative castings from each melt or heat-treatment charge, and crush or cut up and etch, or otherwise prepare the sections for examination, for internal defects. Should injurious defects be found which evidence unsound steel or faulty foundry technique, all of the castings from that particular pattern, melt and heat-treatment charge may be rejected. All the rejected castings, including those cut up, shall be replaced by the manufacturer, without charge. Coarse-grained fracture or other evidence of improper treatment shall be cause for reheat treating.

Workmanship

15. The castings shall conform substantially to the shapes and sizes indicated by the drawings approved.

Finish

16. (*a*) The castings shall be clean and free from injurious defects.

(*b*) The castings shall not be peened to stop leaks.

(*c*) Defects which do not impair the strength of the castings may be welded by an approved process. The defects shall be cleaned out to solid metal, before welding, and shall be submitted to the inspector representing the purchaser in this condition for his approval. All castings shall be heat treated after welding in accordance with the requirements of Sections 3 and 4, except that with permission of the inspector, castings with minor welds need only be drawn or tempered. In the case of major repair welds, the inspector may require examination after reannealing with X-rays or gamma-rays to show the adequacy of the repair, the cost of X-raying or gamma-raying to be borne by the manufacturer, notice of such to be given at the time permission is granted to weld.

Marking

17. (*a*) Valves, flanges and fittings shall be marked in accordance with the Product Marking System (No. SP-25 – 1934) of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position as not to injure the usefulness of the castings.

(*b*) In addition thereto, the pressure containing parts of all cast alloy-steel valves, flanges and fittings of a size and shape permitting, made in accordance with any of the grades of alloy steel covered by these specifications, shall be marked for identification with the A.S.T.M. symbols C 1, C 2, etc.

(*c*) Pressure containing parts of a size and shape permitting, made of alloy-steel grades not covered by these specifications, shall be marked for identification with the manufacturer's individual symbol which should not conflict with any of the A.S.T.M. symbols set up for alloy steel identification.

(*d*) In addition, melt number or melt identification shall be indicated.

Inspection

18. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

19. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within twelve working days from receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

20. Samples tested in accordance with Section 7, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTES

NOTE.—For castings intended for service at temperatures from 500 to 850 F., see Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A.S.T.M. Designation: A 95) of the American Society for Testing Materials.[1]

NOTE 2.—The subcommittee formulating these specifications has included eight grades of material that have been rather extensively used for the present purpose. It is not the intent that these specifications should be limited to these eight alloys. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent. It should also be noted that it is not intended to imply that all of the alloy steels shown are suitable over the entire temperature range. Some are suitable only at lower temperatures, unless low stresses are employed. Pending the incorporation of high-temperature data in an appendix, which it is the purpose in due time to add, high-temperature properties, when it is desired that the same be indicated or specified, shall be a matter of mutual agreement between the purchaser and the manufacturer. No high-temperature tests shall be required on the materials selected unless a matter of agreement between the purchaser and the manufacturer. When required, the short-time tests at elevated temperatures shall be in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 21 - 34 T)[1] and the creep tests shall be in accordance with the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 22 - 35 T)[2] of the American Society for Testing Materials.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 259.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1214 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1406.

[2] See p. 1291.

TENTATIVE SPECIFICATIONS

FOR

SEAMLESS ALLOY-STEEL PIPE FOR SERVICE AT TEMPERATURES FROM 750 TO 1100 F.[1]

A.S.T.M. Designation: A 158 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.[2]

Scope

1. (*a*) These specifications are intended as a general guide for the purchase of alloy-steel pipe and to serve as a basis for agreement between purchaser and manufacturer as to details not specifically covered.

(*b*) These specifications cover seamless alloy-steel pipe intended for service at metal temperatures from 750 to 1100 F.; both ferritic and austenitic steels, designated P 1, P 2, etc., are included (Note 1). The maximum temperature at which the pipe will be operated in service shall be stated in the purchase order. Choice from the respective steels should be made on the basis of the requirements of design, service conditions, and the physical properties (Note 2). Supplementary requirements (Paragraphs S1 to S6) of an optional nature are provided for pipe intended for use in central stations having steam service pressures of 400 lb. per sq. in. or over and temperatures up to 1100 F., or other applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made at the expense of the purchaser, and when desired shall be so stated in the order.

Certification

2. Where mutually agreed upon in writing between the manufacturer and purchaser, a certification that the material conforms to the requirements of these specifications shall be the basis of accept-

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

ance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the chemical analyses and tension tests made in accordance with these specifications.

Process

3. (*a*) The steel shall be made by either or both of the following processes: open-hearth or electric-furnace.

(*b*) Unless otherwise specified, all pipe 2 in. and over in nominal diameter shall be furnished hot-finished followed by the treatment specified in Section 5.

(*c*) Unless otherwise specified, pipe under 2 in. in nominal diameter may be furnished either hot-finished or cold-drawn, with, where necessary, a suitable manufacturer's finishing treatment.

Discard

4. Sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Heat Treatment

5. (*a*) All ferritic steels covered in Section 3 shall be furnished in a full-annealed or normalized and drawn condition as stated in the purchase order. If furnished in the normalized and drawn condition, the temperature for drawing shall be at least 200 F. above the service temperature as given in the purchase order (Note 1).

(*b*) At the option of the purchaser, all austenitic steels shall be stabilized (Note 2) according to present accepted practice.

NOTE 1.—Certain of the ferritic steels covered by these specifications will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 to 6 per cent chromium steels, P 5. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging and hot bending, should be followed by heat treating.

NOTE 2.—Fabricating operations involving upsetting, flanging, bending, and forming often make restabilizing desirable to insure adequate corrosion resistance, depending upon service conditions.

Chemical Composition[1]

6. Each alloy[2] shall conform to the following chemical requirements, or to other chemical requirements as specified in the purchase order:

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

[2] Alloys have been numbered so that similar alloys in the corresponding specifications for forgings, castings, and bolting will bear the same number for alloys numbered 10 or below. No alloys P 4, P 7 or P 10 are included herein as the particular compositions corresponding to these numbers are not included in these specifications.

Class	Ferritic Steels					
Grade	P 1	P 2	P 3	P 5	P 11	P 12
	Carbon-Molybdenum	Manganese-Molybdenum	Chromium-Molybdenum	4 to 6 per cent Chromium	Chromium-Molybdenum	Nickel-Molybdenum
Carbon, per cent	0.10 to 0.20	0.10 to 0.20	0.10 to 0.20	0.10 to 0.20	0.10 to 0.20	0.10 to 0.20
Manganese, per cent	0.30 to 0.60	1.10 to 1.40	0.40 to 0.60	0.50 max.	0.30 to 0.50	0.30 to 0.60
Phosphorus, per cent	0.04 max.	0.04 max.	0.03 max.	0.03 max.	0.03 max.	0.04 max.
Sulfur, per cent	0.045 max.	0.045 max.	0.04 max.	0.03 max.	0.03 max.	0.045 max.
Silicon, per cent	0.20 to 0.50	0.20 to 0.50	0.45 to 0.75	0.50 max.	0.75 to 1.25	0.50 max.
Nickel, per cent	....	....	....	....	....	1.50 to 2.00
Chromium, per cent	....	....	1.50 to 2.00	4.00 to 6.00	1.00 to 1.50	....
Molybdenum, per cent	0.45 to 0.65	0.20 to 0.30	0.60 to 0.80	0.45 to 0.65[a]	0.40 to 0.60	0.20 to 0.30
Tungsten, per cent	....	....	....	0.75 to 1.25[a]	....	....

Class	Ferritic Steel	Austenitic Steels		
Grade	P 6	P 8	P 9	P 13
	13 per cent Chromium	18 Chromium 8 Nickel	18 Chromium 8 Nickel	18 Chromium 8 Nickel 2 Silicon
Carbon, per cent	0.12 max.	0.07 max.	0.16 max.	0.25 max.
Manganese, per cent	0.50 max.	0.20 to 0.70	0.20 to 0.70	0.50 to 0.70
Phosphorus, per cent	0.025 max.	0.03 max.	0.03 max.	0.03 max.
Sulfur, per cent	0.025 max.	0.03 max.	0.03 max.	0.03 max.
Silicon, per cent	0.50 max.	0.70 max.	0.70 max.	1.00 to 3.00
Nickel, per cent	....	7.00 to 9.00	7.00 to 9.00	8.00 to 10.00
Chromium, per cent	12.00 to 15.00	17.00 to 19.00	17.00 to 19.00	17.00 to 19.00
Molybdenum, per cent	....	....	....	....
Tungsten, per cent	2.50 to 3.50	....	....	....

[a] Either molybdenum or tungsten may be used, if desired.

Ladle Analysis

7. A ladle analysis of each melt of steel shall be made by the steel manufacturer. The chemical composition thus determined, or that determined from a check analysis made by the pipe manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

Check Analysis

8. (*a*) At the request of the purchaser's inspector, analyses as specified below shall be made by the manufacturer from the finished pipe and shall conform to the requirements specified in Section 6:

NOMINAL DIAMETER	NUMBER OF PIPES SELECTED
Under 2 in.	2 pipes from each lot of 400 lengths or fraction thereof
2 to 5 in. inclusive	2 pipes from each lot of 200 lengths or fraction thereof
6 in. and over	2 pipes from each lot of 100 lengths or fraction thereof

Results of these analyses shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 6.

(*b*) Drillings for analysis from pipe shall be taken from several points around each pipe selected for analysis. Drillings for analysis from billets shall be taken at a point midway between the outside and center of the billet by drilling parallel to the axis.

(*c*) If the analysis of one of the tests specified in Section 7 or 8 (*a*) does not conform to the requirements specified in Section 6, analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

Tension Tests

9. (*a*) The material shall conform to the following minimum requirements as to tensile properties[1] at room temperature:

	FERRITIC STEELS	AUSTENITIC STEELS
Tensile strength, lb. per sq. in.	60 000[a]	75 000[a]
Yield point, lb. per sq. in.:		
Fully annealed	25 000[a]	......
Normalized and drawn	30 000[a]	......
Rapidly air-cooled or quenched	......	30 000[a]
Elongation in 2 in., per cent	30[a]	50[a]

[a] For transverse tension tests the material shall conform to these minimum tensile requirements except that the elongation in 2 in. shall be 25 per cent for the ferritic steels and 40 per cent for the austenitic steels.

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers or other approved method, at a cross-head speed not to exceed $\frac{1}{8}$ in. per minute. Where a definite yield point is not exhibited, the yield strength, corresponding to a limiting permanent set of 0.2 per cent of the gage length of the specimen, shall be reported instead. The "set method" of determining yield strength as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[2] shall be followed. The tensile strength shall be determined at a crosshead speed not to exceed $1\frac{1}{2}$ in. per minute.

Hydrostatic Tests

10. (*a*) Unless otherwise mutually agreed upon between the manufacturer and purchaser, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress of 50 per cent of the minimum specified yield point

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

[2] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

at room temperature. This pressure shall be determined by the formula:

$$P = \frac{2St}{D}$$

where P = the minimum hydrostatic test pressure in pounds per square inch;

S = 0.50 times the minimum specified yield point at room temperature in pounds per square inch;

t = the nominal wall thickness in inches; and

D = the outside diameter in inches.

(*b*) The maximum hydrostatic test pressure shall not exceed 2500 lb. per sq. in. for sizes 3 in. or under in outside diameter, nor 4500 lb. per sq. in. for sizes over 3 in. in outside diameter. The hydrostatic pressure shall be maintained for not less than 5 sec.

Flattening Tests

11. For pipe over 2 in. in nominal diameter, a section of pipe not less than 2½ in. in length shall be flattened between parallel plates until the opposite walls of the pipe meet. No cracks or breaks in the metal shall occur until the distance between the plates is less than one half the outside diameter of the pipe, but in no case less than seven times the thickness of the pipe wall. Evidence of laminations or burnt material shall not develop during the entire flattening process.

Bend Tests

12. For pipe 2 in. or under in nominal diameter, a sufficient length of pipe shall stand being bent cold through 90 deg. around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180 deg. around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

Test Specimens

13. (*a*) Specimens cut either longitudinally or transversely shall be acceptable for tension tests.

(*b*) Longitudinal tension tests may be made in full section of the pipe up to the capacity of the testing machine. For larger sizes, the tension test specimens shall consist of strips cut from the pipe. The width of these specimens shall be 1½ in. and shall have a gage length of 2 in. When the pipe wall thickness exceeds ¾ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Longitudinal tension specimens shall not be flattened between gage marks. The sides of specimens shall be parallel between gage marks.

(*c*) The transverse tension test may be made on pipe 8 in. and over in nominal diameter. Specimens may be taken from a ring cut from the pipe or from sections resulting from the flattening tests. The specimen shall consist of a strip cut transversely from the pipe; the width of the specimen shall be 1½ in. and its gage length 2 in. When the pipe wall thickness exceeds ¾ in., the A.S.T.M. standard 0.505-in. round specimen shall be used (Note). Specimens shall be flattened cold and shall be parallel between gage marks. At the option of the manufacturer, the transverse tension test specimen may be machined off on either surface provided not over 15 per cent of the nominal thickness is removed from either side.

NOTE.—The standard tension test specimens are described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

(*d*) Test specimens for flattening and bend tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

(*e*) All routine check tests shall be made at room temperature.

Number of Tests

14. (*a*) Tests shall be made as follows on one pipe from each heat-treated lot, but in no case on less than 5 per cent of the pipe ordered. Results of these tests shall be reported to the purchaser or his representative:

One transverse or longitudinal tension test specified in Section 9.

The flattening test specified in Section 11 for pipe over 2 in. in nominal diameter.

The bend test specified in Section 12 for pipe 2 in. or under in nominal diameter.

(*b*) For material heat treated by the continuous process, the tests specified in Section 14 (*a*) shall be made on each pipe in a lot constituting 5 per cent of the pipe ordered, but on not less than two pipes.

(*c*) Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

Retests

15. (*a*) If the results of any physical tests of any lot do not conform to the requirements specified in Sections 9, 11, or 12, retests shall be made on additional pipes of double the original number from

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

the same lot, each of which shall conform to the requirements specified.

(*b*) If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of the specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

(*c*) If any specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

Retreatment

16. If individual lengths of pipe selected to represent any lot fail to meet the test requirements of Sections 9, 11, or 12, the lot may be heat treated again and resubmitted for test, except that any individual lengths which meet the test requirements before retreating will be acceptable.

Permissible Variations in Weight and Dimensions

17. (*a*) *Weight.*—The weight of any length of pipe in sizes up to and including 12 in. shall not vary more than 3.5 per cent under and 6.5 per cent over that specified. For sizes over 12 in. the weight of any length shall not vary more than 5 per cent under and 10 per cent over that specified. Unless otherwise mutually agreed upon between the manufacturer and purchaser, pipe in sizes smaller than 4 in. may be weighed in convenient lots; pipe in sizes 4 in. and larger shall be weighed separately.

(*b*) *Diameter.*—Variations in outside diameter shall not exceed those shown in the following table:

NOMINAL DIAMETER	PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETERS	
	UNDER	OVER
$\frac{1}{8}$ to $1\frac{1}{2}$ in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{64}$ in. (0.015 in.)
2 to 4 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{32}$ in. (0.031 in.)
5 to 8 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{16}$ in. (0.062 in.)
10 to 18 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{3}{32}$ in. (0.093 in.)
20 to 24 in., inclusive	$\frac{1}{32}$ in. (0.031 in.)	$\frac{1}{8}$ in. (0.125 in.)

(*c*) *Thickness.*—The minimum wall thickness at any point shall not be more than 12.5 per cent under the nominal wall thickness specified.

(*d*) *Length.*—Pipe lengths shall be in accordance with the following regular practice:

> The lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. over that specified.
>
> No jointers are permitted unless otherwise specified.

Ends

18. Unless otherwise specified, pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

Finish

19. (*a*) The finished pipe shall be reasonably straight and free from injurious defects, and shall have a workmanlike finish.

Depth of Injurious Defects

(*b*) When the depth of defect in the pipe encroaches on the minimum wall thickness (87.5 per cent of the nominal thickness), or is in excess of 12.5 per cent of the nominal wall thickness, such defects shall be considered injurious.

Machining or Grinding Defects

(*c*) Pipe showing moderate slivers may be machined or ground inside or outside to a depth which shall insure the removal of all included scale and slivers, providing the wall thickness is not reduced below the minimum wall thickness required in these specifications. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

Repair by Welding

(*d*) Repair of injurious defects shall be permitted only subject to the approval of the purchaser and with the further understanding that the composition of the welding rod shall be suitable for the composition of the metal being welded. Welding of injurious defects in no case shall be permitted when the depth of defect exceeds $33\frac{1}{3}$ per cent of the nominal pipe wall thickness or the length of repair exceeds 25 per cent of the nominal diameter of the pipe. Defects shall be thoroughly chipped out before welding, and then heat treated in accordance with Section 5. Each length of repaired pipe shall be retested hydrostatically in accordance with Section 10.

Marking

20. Each length of pipe manufactured in accordance with these specifications shall be legibly marked, either by stenciling, stamping, or rolling, with the manufacturer's private identifying mark, together with the symbols A 158 and the alloy symbol (as A 158 – P1) and an additional S if pipe meets the supplementary requirements specified in Paragraphs S1 to S7. Marking shall be within 12 in. of one end of each length. On pipe sizes 4 in. and larger, the weight shall be given. On small diameter pipe which is bundled, the above information may be legibly stamped on a metal tag securely attached to each bundle. When pipe marked as specified in this section is rejected, the designation A 158 shall be canceled.

Inspection

21. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment and at the manufacturer's expense, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

22. Each length of pipe which develops injurious defects in shop working or application shall be rejected, and the manufacturer shall be notified. No rejections under these or any other specifications, shall be marked as specified in Section 20 for sale under these specifications except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

Supplementary Requirements Appear on Pages 614 and 615.

SUPPLEMENTARY REQUIREMENTS FOR SEAMLESS PIPE FOR USE IN CENTRAL STATIONS AT PRESSURES OF 400 LB. PER SQ. IN., OR OVER, AND TEMPERATURES OF 750 F. TO 1100 F., OR OTHER APPLICATIONS WHERE A SUPERIOR GRADE OF PIPE IS REQUIRED

S1. These requirements shall not be considered unless specified in the order, in which event the supplementary tests shall be made at the mill, unless otherwise agreed upon, at the purchaser's expense and witnessed by his inspector before shipment of the material.

Check Analysis

S2. Check analysis may be made on any length of pipe. Individual lengths failing to meet the chemical requirements specified in Section 6 shall be rejected.

Transverse Tension Tests

S3. Transverse tension tests may be made on specimens from both ends of each length of pipe. If the specimen from either end of any length fails to meet the physical properties specified in Section 9, that length shall be rejected.

Flattening Tests

S4. The flattening tests specified in Section 11 may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to meet the specified requirements, that length shall be rejected.

Finish and Metal Structure

S5. The finished pipe shall be free from all immoderate slivers and depressions. The steel shall have a homogeneous structure as shown by the etching test in Paragraph S6.

Etching Tests

S6. Etching tests[1] may be made on sections from any pipe, and shall show sound and reasonably uniform material, free from injurious laminations, cracks and similar objectionable defects. Sections used for the flattening tests described in Section 11 may be used for the etching test. If the specimen from any length shows objectionable defects, that length may be rejected.

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[1] Pending development of etching methods applicable to the product covered by these specifications, it is recommended the Tentative Recommended Practice for a Standard Macro-Etch Test for Steel described in the *National Metals Handbook*, Am. Soc. for Metals, 1933 edition, p. 639, be followed.

Rejection

S7. At the purchaser's discretion, if 10 per cent of the pipe in any one lot fail to meet the requirements of Paragraphs S2 to S6, the entire lot may be rejected. Rejection of a lot shall be based on tests from not less than two pipes. A lot shall consist of all the pipe bought by a purchaser of the same size and wall thickness from any one heat.

EXPLANATORY NOTES

NOTE 1.—The subcommittee formulating these specifications has included several classes of material that have been rather extensively used. Upon mutual agreement between the manufacturer and purchaser, other classes of material may be employed, provided they otherwise meet the requirements of these specifications. Other compositions will be considered for inclusion in these specifications by the committee from time to time as the need becomes apparent.

NOTE 2.—Pending the incorporation of high-temperature data in an appendix, which it is the purpose in due time to add, high-temperature properties, when it is desired that the same be indicated or specified, shall be a matter of agreement between the manufacturer and purchaser. No high-temperature tests shall be required on the materials selected unless a matter of agreement between the manufacturer and purchaser. When required, the short-time tests at elevated temperature shall be in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 21 - 34 T)[1] and the creep tests shall be in accordance with the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 22 - 35 T)[2] of the American Society for Testing Materials.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1214 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1406.

[2] See p. 1291.

TENTATIVE SPECIFICATIONS

FOR

FORGED OR ROLLED ALLOY-STEEL PIPE FLANGES, FORGED FITTINGS, AND VALVES AND PARTS FOR SERVICE AT TEMPERATURES FROM 750 TO 1100 F.[1]

A.S.T.M. Designation: A 182 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. (*a*) These specifications cover forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts intended for service at metal temperatures from 750 to 1100 F. (Note 1). The term "forgings" used herein shall be understood to cover one or all of the products mentioned above, either forged or rolled.

(*b*) Ten grades of material are included covering ferritic steels and austenitic steels, designated F 1, F 2, etc., and classified in accordance with their chemical and physical properties as specified in Sections 8 and 11. Choice from the several steels should be made on the basis of the requirements of design and service conditions, physical properties, and the high-temperature characteristics (Note 2).

Certification of Test

2. Where mutually agreed upon in writing between the purchaser and manufacturer, a certification that the material conforms to the requirements specified may be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the chemical analysis and tension tests made in accordance with these specifications.

Process

3. The steel may be made by the electric-furnace, open-hearth, or other process approved by the purchaser.

Discard

4. Sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation. The steel shall have a homogeneous structure as shown by the macro-etch test in Section 16.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Forging Practice

5. (*a*) Material for forgings shall consist of blooms, billets, slabs, or bars either forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

(*b*) Forging or rolling operations may be performed either by hammering, pressing, rolling, extruding, or upsetting. Forgings shall be brought as nearly as practicable to the finished shape and size by hot working and shall be so processed as to cause metal flow during the hot-working operation in the direction most favorable for resisting the stresses encountered in service.

(*c*) When specified in the purchase order, a sample forging may be sectioned and etched to show flow lines and the condition as regards internal imperfections. In such cases, the question of acceptable and unacceptable character of metal flow shall be a subject for agreement between the purchaser and manufacturer.

(*d*) When specified in the purchase order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

Heat Treatment Required

6. (*a*) All forgings shall receive a heat treatment suitable to their design and chemical composition. Heat treatment shall be performed before machining except when re-heat treatment is necessary. Unless otherwise agreed on, the method of heat treatment shall be at the option of the manufacturer.

(*b*) Heat treatment for the ferritic steels may consist of full annealing, normalizing, full annealing and normalizing, or full annealing and/or normalizing followed by tempering. Liquid quenching shall be permitted for austenitic steels only, except as may be otherwise agreed upon by the purchaser and manufacturer.

(*c*) Austenitic steels shall receive a stabilizing treatment as described in Section 7 (*d*).

Heat Treatment

7. (*a*) *Full Annealing.*—The procedure for full annealing shall consist in allowing the forgings, immediately after forging or rolling, to cool to a temperature below the critical range under suitable conditions to prevent injuries by too rapid cooling. They shall then be uniformly reheated to the proper temperature and for the required time to refine the grain, and cooled slowly thereafter in the furnace or in lime. The forgings shall not be removed from the furnace or the lime until a metal temperature of approximately 500 F. (260 C.) has been attained.

(*b*) *Normalizing.*—The procedure for normalizing shall consist in allowing the forgings, immediately after forging or rolling, to cool to a temperature below the critical range, under suitable conditions to prevent injuries by too rapid cooling. They shall then be uniformly reheated to the proper temperature and held there a sufficient time to refine the grain (a group thus reheated being known as a "normalizing charge"), followed by cooling in still air at room temperature.

(*c*) *Tempering or Drawing.*—The procedure for tempering or drawing shall consist in reheating the forgings to a temperature at least 200 F. (93 C.) above the temperature to be encountered in service, holding at that temperature for not less than 1 hr. per inch of thickness at the thickest section, followed by cooling in the furnace or in still air.

(*d*) *Stabilizing.*—The procedure for stabilizing austenitic steels shall consist in holding the forgings for sufficient time at the stabilizing temperature, followed by rapid air cooling or by quenching in a liquid medium if required, to meet the physical properties specified.

Chemical Composition[1]

8. Each alloy[2] shall conform to the following requirements as to chemical composition or to other chemical requirements as specified on the purchase order:

Class	Ferritic Steels				
Identification Symbol	F 1	F 3	F 4	F 5	F 6
Grade	Carbon-Molybdenum	Chromium-Molybdenum	Nickel-Chromium-Molybdenum	4-6 Per Cent Chromium	13 Per Cent Chromium
Carbon, per cent	0.35 max.	0.15 to 0.25	0.35 to 0.45	0.15 to 0.25	0.12 max.
Manganese, per cent	0.30 to 0.80	0.40 to 0.60	0.40 to 0.70	0.30 to 0.50	0.50 max.
Phosphorus, per cent	0.04 max.	0.04 max.	0.05 max.	0.04 max.	0.03 max.
Sulfur, per cent	0.045 max.	0.04 max.	0.05 max.	0.04 max.	0.03 max.
Silicon, per cent	0.20 to 0.50	0.45 to 0.75	...	0.50 max.	0.50 max.
Nickel, per cent	...	...	1.50 to 2.00	...	0.50 max.
Chromium, per cent	...	1.50 to 2.00	0.55 to 0.85	4.00 to 6.00	11.5 to 13.0
Molybdenum, per cent	0.40 to 0.60	0.60 to 0.80	0.30 to 0.40	0.40 to 0.60[a]	...
Tungsten, per cent	...	...	...	0.80 to 1.25[a]	...
Titanium, per cent	...	...	...	1.00 max.[b]	...

Class	Ferritic Steels	Austenitic Steels		Ferritic Steel	Austenitic Steel
Identification Symbol	F 7	F 8	F 10	F 11	F 12
Grade	Chromium-Molybdenum	18 Chromium 8 Nickel	20 Nickel 8 Chromium	Chromium-Manganese-Molybdenum	20 Nickel 8 Chromium
Carbon, per cent	0.25 to 0.40	0.07 max.	0.10 to 0.20	0.25 to 0.40	0.45 max.
Manganese, per cent	0.40 to 0.85	0.50 max.	0.50 to 0.70	1.20 to 1.50	0.50 to 0.70
Phosphorus, per cent	0.05 max.	0.03 max.	0.03 max.	0.05 max.	0.03 max.
Sulfur, per cent	0.05 max.	0.03 max.	0.03 max.	0.05 max.	0.03 max.
Silicon, per cent	0.15 to 0.45	0.20 to 0.40	1.00 to 1.40	0.40 to 0.60	0.90 to 1.25
Nickel, per cent	...	7.00 to 10.0[c]	19.0 to 22.0	...	19.0 to 22.0
Chromium, per cent	0.75 to 1.10	17.0 to 20.0[c]	7.00 to 9.00	0.60 to 0.90	7.00 to 9.00
Molybdenum, per cent	0.15 to 0.25	...	...	0.25 to 0.40	...
Tungsten, per cent	...	...	...	...	...
Titanium, per cent	...	0.50[b]	...	...	...

[a] Either molybdenum or tungsten shall be used. [b] May be added.
[c] Sum of chromium and nickel contents shall not be less than 26 per cent.

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manfuacturer.

[2] Alloys have been numbered so that similar alloys in the corresponding specifications for pipe, castings, and bolting will bear the same number for alloys numbered 10 or below. No alloys F 2 or F 9 are included herein as the particular compositions corresponding to these numbers are not included in these specifications.

Ladle Analyses

9. A ladle analysis of each melt of steel shall be made by the steel manufacturer to determine the percentage of the elements specified. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot obtained during the pouring of a melt. The chemical composition thus determined, or that determined from a check analysis made by the forgings manufacturer, shall be reported to the purchaser or his representative and shall conform to the requirements specified.

Check Analyses

10. Analysis representing each melt may be made by the purchaser from one forged or rolled flange, fitting, or valve or part, or from broken tension test specimens. The chemical composition thus determined shall conform to the requirements specified. All drillings for check analysis shall be taken at least ¼ in. beneath the surface, or turnings may be taken from test specimens.

Tension Tests

11. *(a)* The forgings shall conform to the following minimum requirements as to tensile properties[1] at room temperature:

	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent
Grade F 1	70 000	45 000	25	35
Grade F 3	70 000	40 000	20	40
Grade F 4	90 000	70 000	18	50
Grade F 5	90 000	65 000	22	50
Grade F 6	85 000	55 000	25	60
Grade F 7	100 000	75 000	18	50
Grade F 8	80 000	40 000	35	50
Grade F 10	80 000	35 000	40	60
Grade F 11	100 000	70 000	17	30
Grade F 12	100 000	45 000	50	60

(b) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine, or by the use of dividers, at a crosshead speed not to exceed ⅛ in. per min. Where a definite yield point is not exhibited, the yield strength corresponding to a limiting permanent set of 0.2 per cent of the gage length of the specimen shall be used instead. The "set method" of determining yield strength as described in the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials[2] shall be followed. The tensile strength shall be determined at a crosshead speed of not to exceed 1½ in. per min.

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[1] When material is ordered for welding fabrication, chemical and physical requirements shall be a matter of agreement between the purchaser and the manufacturer.

[2] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

(*c*) The yield strength, where given, shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine.

Hydrostatic Tests

12. Valve bodies or fittings and other pressure-containing parts shall be tested after machining to a hydrostatic pressure of four times the primary service pressure rating. No hydrostatic test is required for welding neck or other flanges.

Number of Tests

13. (*a*) One tension test at room temperature shall be made by the manufacturer from each melt in each heat treatment charge. The results of these tests shall be reported to the purchaser or his representative.

(*b*) For purpose of tests, the necessary extra forgings or test bars shall be provided to furnish the specimens required in Paragraph (*a*). The test specimen if cut from a flange shall be cut tangentially from the flange portion approximately midway between the inner and outer surfaces and approximately midway between the front and back faces. When it is impracticable to provide extra forgings for test purposes, test bars may be made from the billet or bar, provided they are given approximately the same reduction and heat treatment as the forgings.

Tension Test Specimens

14. (*a*) The tension test specimens taken from the forgings, billets, or bars shall be machined and shall be of the usual type for 2-in. gage length as described in Section 15 of the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1] The diameter of the test specimen shall be 0.505 in. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*b*) In the case of small sections which will not permit of taking the standard test specimen specified in Paragraph (*a*), the tension test specimen shall be as large as feasible and its dimensions shall be proportional to those of the standard test specimen specified in Paragraph (*a*). The gage length for measuring elongation shall be four times the diameter of the specimen.

Retests

15. (*a*) If any of the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-treat such lots not to exceed twice and retests shall be made as specified in Section 13 (*a*).

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

(*b*) If any test specimen shows defective machining, it may be discarded and another specimen substituted from the same melt and heat treatment charge.

(*c*) If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Macro-Etch Tests

16. In case of question as to the soundness of material in any lot of forgings and its suitability for the intended service, a macro-etching test shall be made for each melt present in the lot. Etching tests[1] shall show sound and reasonably uniform material, free from injurious laminations, cracks, segregations, and similar objectionable defects. If on successive tests 10 per cent of any melt fail to pass the requirements of the macro-etch test, all forgings from that melt shall be rejected.

Workmanship and Finish

17. (*a*) The forgings shall conform to the sizes and shapes specified by the purchaser.

(*b*) The forgings shall be free from injurious defects and shall have a workmanlike finish.

Identification

18. Identification marks consisting of the manufacturer's symbol or name, designation of service rating, the designation F 1, F 2, etc., showing the class of material, and the size shall be stamped legibly on each forging in accordance with the Product Marking System (No. SP-25 – 1934) of the Manufacturers Standardization Society of the Valve and Fittings Industry.

Inspection

19. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. All routine tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment and at the manufacturer's expense, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

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[1] Pending development of etching methods applicable to the product covered by these specifications, it is recommended that the Tentative Recommended Practice for a Standard Macro-Etch Test for Steel, described in the *National Metals Handbook*, Am. Soc. for Metals, 1933 Edition, p. 639, be followed.

Rejection

20. (*a*) Unless otherwise specified, any rejection based on tests shall be reported within twelve working days from the receipt of samples or test reports.

(*b*) Each forging which develops injurious defects in shop working or application shall be rejected and the manufacturer notified. Where such defect occurs, the purchaser shall be entitled to conduct at his own expense such check tests as may be necessary to demonstrate the acceptability of the balance of the lot. At the purchaser's discretion, if 10 per cent of the forgings in any melt of a heat treatment charge fail to meet the specified chemical and physical requirements, the entire lot may be rejected.

Rehearing

21. Samples tested in accordance with Sections 10 and 16, which represent rejected forgings shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTES

NOTE 1.—The subcommittee formulating these specifications has included ten grades of material that have been rather extensively used. Upon agreement between the purchaser and manufacturer, other classes of material may be employed, provided they otherwise meet the requirements of these specifications. Other compositions will be considered for inclusion in these specifications by the committee from time to time as the need becomes apparent. It should be noted that it is not intended to imply that all the alloy steels shown are suitable over the entire temperature range. Some are suitable only at lower temperatures, unless low stresses are employed.

NOTE 2.—High-temperature properties, when it is desired that they be indicated or specified, shall be a matter of agreement between the purchaser and manufacturer pending the incorporation of high temperature data in an appendix, which it is the intention to add in due time. No high-temperature tests shall be required on the materials selected unless made a matter of agreement between the purchaser and manufacturer. When required, the short-time tests at elevated temperature shall be in accordance with the Tentative Method of Test for Short-Time High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 21-34 T),[1] and the creep tests shall be in accordance with the Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (A.S.T.M. Designation: E 22 – 35 T)[2] of the American Society for Testing Materials.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1214 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1406.

[2] See p. 1291.

TENTATIVE SPECIFICATIONS

FOR

12 PER CENT CHROMIUM STEEL CASTINGS[1]

A.S.T.M. Designation: A 168 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover the 11.5 to 14 per cent chromium type of stainless steel castings, of 0.15 per cent, maximum, carbon content (Note).

NOTE.—Certain castings for high resistance to compression and/or abrasion are made of a similar composition but of higher carbon content; these specifications are not intended to cover such castings.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All castings shall receive a heat treatment proper to the design of the casting.

(*b*) Heat treatment of the castings, unless otherwise specified by the purchaser, shall consist of a normalizing followed by drawing, and then cooling in air. The normalizing temperature shall be not less than 1875 F. (1024 C.) and the drawing temperature shall be not less than 1100 F. (595 C.) nor greater than 1350 F. (680 C.) (Notes 1 and 2).

NOTE 1.—If a lower drawing temperature is desirable, it should be less than 900 F. (485 C.) in order to preserve the maximum corrosion resistance.

NOTE 2.—This alloy responds to oil quenching, particularly as the carbon approaches the maximum limit.

Chemical Composition

4. (*a*) The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.15[a]
Chromium, per cent	11.5 to 14.0[a]
Manganese, per cent	0.25 to 0.75
Silicon, max., per cent	1.00
Nickel, max., per cent	0.80
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

[a] If the carbon content exceeds 0.12 per cent, the chromium content shall not be less than 12.50 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, if requested, and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

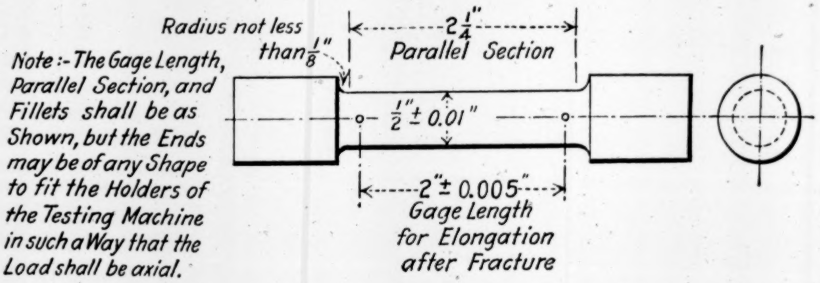
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
Note :- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Tension Tests

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	80 000
Yield point, min., lb. per sq. in.	50 000
Elongation in 2 in., min., per cent	20
Reduction of area, min., per cent	30

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. (*a*) Bend tests shall be required for castings only when so specified in the inquiry and order.

(*b*) When a bend test is specified, the test specimen shall stand being bent cold through an angle of 90 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 215.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Test Specimen

10. (*a*) Tension and bend test specimens, when required, shall be taken from test bars cast attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service, test bars shall be required to be attached to the castings when so specified in the inquiry or order.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Bend test specimens, when required, shall be machined to 1 by ½ in. in section with the corners rounded to a radius not over $\frac{1}{16}$ in.

(*d*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion resistance is usually of prime importance in this alloy, tension tests shall be required only when specified in the inquiry or order. In such cases, one tension test, and when specified, one bend test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

(*d*) If the percentage of elongation of any tension specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be reheat-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale and injurious defects. Seams that are judged to be other than superficial will be sufficient to cause rejection of castings.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

NOTE.—Usually a 16 to 18 per cent chromium, 0.15 per cent carbon rod is employed for such welding with good results.

Marking

15. Castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples by the purchaser.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

19 PER CENT CHROMIUM STEEL CASTINGS[1]

A.S.T.M. Designation: A 169 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover corrosion-resisting and heat-resisting steel castings of the 17 to 21 per cent chromium type with 0.30 per cent, maximum, carbon content (Note).

NOTE.—Certain castings for high resistance to compression and/or abrasion are made of a similar composition but of higher carbon content; these specifications are not intended to cover such castings.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All castings shall receive a heat treatment mainly for the purpose of stress relief.

(*b*) Heat treatment of the castings, unless otherwise specified by the purchaser, shall consist of an anneal at between 1450 and 1550 F. (790 to 845 C.) for a sufficient period depending on sections involved, cooling in furnace to 1100 F. (595 C.) and then removing into the air (Note).

NOTE.—It is desired that the cooling be fairly rapid through the range 1050 to 900 F. (565 to 485 C.) in order to prevent inter-crystalline precipitation which affects corrosion resistance in certain cases.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.30
Chromium, per cent	17.0 to 21.0
Manganese, per cent	0.25 to 0.75
Silicon, max., per cent	1.00
Nickel, max., per cent	1.00
Copper, per cent	0.90 to 1.20[a]
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

[a] Copper is required for heat-resisting castings.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface.

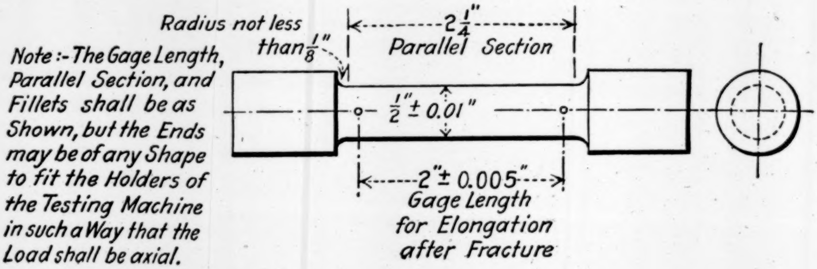
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Tension Tests

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	90 000
Yield point, min., lb. per sq. in.	55 000
Elongation in 2 in., min., per cent	5.0
Reduction of area, min., per cent	5.0

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. No bend tests shall be required.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 230.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

Test Specimens

10. (*a*) Tension test specimens shall be taken from test bars attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service, test bars shall be required to be attached to the castings, when so specified in the inquiry or order.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion resistance and heat resistance are usually of prime importance in this alloy, tension tests shall be required only when specified in the inquiry or order. In such cases one tension test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

(*d*) If the percentage of elongation of any tension specimen is less than that specified in Section 7(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale and injurious defects. Seams that are judged to be other than superficial will be sufficient to cause rejection of castings.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

NOTE.—Usually a 16 to 18 per cent chromium, 0.15 per cent carbon rod is employed for such welding with good results.

Marking

15. Castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples by the purchaser.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
28 PER CENT CHROMIUM STEEL CASTINGS[1]

A.S.T.M. Designation: A 170 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover corrosion-resisting and heat-resisting steel castings of the 26 to 30 per cent chromium type with 0.50 per cent, maximum, carbon content (Note).

NOTE.—Certain castings for high heat resistance and/or abrasion resistance are made of a similar composition but of higher carbon content; these specifications are not intended to cover such castings.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All corrosion-resisting castings shall receive a stress-relieving treatment. They shall be annealed at between 1450 and 1550 F. (790 to 845 C.) and cooled slowly in the furnace to 1100 F. (595 C.) and then cooled in the air from that temperature (Notes 1 and 2).

(*b*) Castings for high-temperature service need not be heat-treated unless specifically requested in the order.

NOTE 1.—Heavy sections may be cooled in water instead of in air from 1100 F. (595 C.) if maximum impact toughness is required.

NOTE 2.—Where castings are of small dimensions and simple in design, they may be water quenched from 1650 F. (900 C.) with no further treatment to get most satisfactory machinability.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, per cent	0.25 to 0.50
Chromium, per cent	26.00 to 30.00
Manganese, per cent	0.25 to 0.75
Silicon, max., per cent	0.80
Nickel, max., per cent	3.00
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. An analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface.

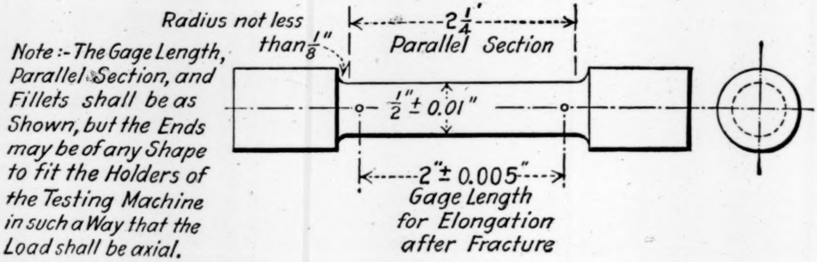
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Tension Tests

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	55 000
Yield point, min., lb. per sq. in.	40 000

(*b*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine at a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. No bend tests shall be required.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 230.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

Test Specimen

10. (*a*) Tension test specimens shall be taken from test bars cast attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service, test bars shall be required to be attached to the castings when so specified in the inquiry or order.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion-resistance or heat-resistance (or both) are usually of prime importance in the use of this alloy, tension tests shall be required only when specified in the inquiry or order. In such cases one tension test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be reheat-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale and injurious defects. Seams that are judged to be other than superficial will be sufficient to cause rejection of castings.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

Marking

15. Castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples by the purchaser.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

24 PER CENT CHROMIUM, 12 PER CENT NICKEL ALLOY STEEL CASTINGS[1]

A.S.T.M. Designation: A 171 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover alloy-steel castings of the 24 per cent chromium, 12 per cent nickel type (Note).

NOTE.—This alloy has been used for applications requiring strength and scale resistance at elevated temperatures, and also for corrosion resistance at normal and/or high temperatures.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All castings shall receive a heat treatment proper to their design.

(*b*) Heat treatment of castings intended for corrosion-resisting applications, unless otherwise specified by the purchaser, shall consist of thorough heating at a temperature of not less than 1875 F. (1024 C.), followed by quenching in water or air, depending upon the character of the castings. Intricate castings may require drawing for strain relief which should be done thoroughly at a temperature not in excess of 800 F. (427 C.).

(*c*) Castings intended for heat-resistance applications need not be heat treated, unless specified by the purchaser for purpose of strain relief.

(*d*) This type alloy is intended for use in castings in which the size and design will permit rapid cooling of all parts from the heat-treating temperature (minimum 1875 F. (1024 C.)), to 800 F. (427 C.). For massive or intricate castings, with which it is impracticable to obtain a rate of cooling sufficiently rapid to prevent harmful carbide precipitation, it may be preferable to either introduce stabilizing elements (molybdenum, titanium, columbium or vanadium), or employ a chromium-nickel alloy having a minimum chromium content of 28.0 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.25[a]
Chromium, per cent	22.0 to 26.0
Nickel, per cent	11.0 to 13.0
Manganese, per cent	0.25 to 1.00
Silicon, per cent	0.25 to 1.50
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

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[a] Castings intended for heat-resisting applications may have a carbon content of 0.40 per cent, maximum.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative if requested, and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least ¼ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Tension Tests

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	70 000
Yield point, min., lb. per sq. in.	0.45 tens. str.
Elongation in 2 in., min., per cent	30
Reduction of area, min., per cent	30

(*b*) The yield point shall be determined by the dividers method, using a cross-head speed not to exceed ⅛ in. per min. The tensile strength shall be determined at a speed of head not to exceed 1½ in. per min.

Bend Tests

8. (*a*) Bend tests shall be required for castings only when so specified in the inquiry and order.

(*b*) When a bend test is specified, the test specimen shall stand being bent cold through an angle of 120 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 200.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Test Specimens

10. (*a*) Tension and bend test specimens, when required, shall be taken from test bars cast attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service and where practicable, test bars shall be required to be attached to the castings, when so stated in the inquiry or order.

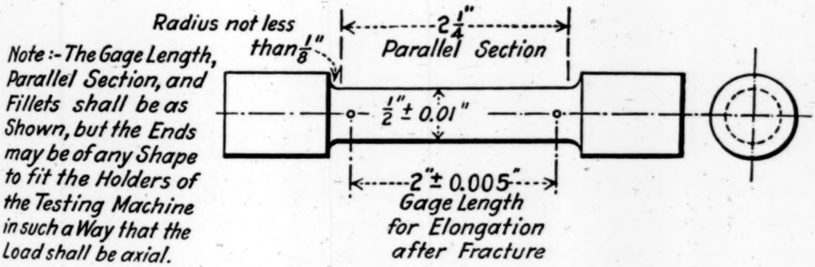
Radius not less than 1/8"
2 1/4"
Parallel Section
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Bend test specimens shall be machined to 1 by ½ in. in section with the corners rounded to a radius not over $\frac{1}{16}$ in.

(*d*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion resistance is usually of prime importance in this alloy, tension tests shall be required only when stated in the inquiry or order. In such cases, one tension test, and when specified, one bend test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

(*d*) If the percentage of elongation of any tension specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale and injurious defects. Seams, folds and pits which are other than superficial and which shall be injurious to the service life of the casting will be sufficient cause for rejection.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

Marking

15. Where practicable, castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

25 PER CENT CHROMIUM, 20 PER CENT NICKEL ALLOY STEEL CASTINGS[1]

A.S.T.M. Designation: A 172 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover alloy-steel castings of the 25 per cent chromium, 20 per cent nickel type (Note).

NOTE.—This alloy has been used for applications requiring strength and scale resistance at elevated temperatures, and also for corrosion resistance at normal and/or high temperatures.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All castings shall receive a heat treatment proper to their design.

(*b*) Heat treatment of castings intended for corrosion-resisting applications, unless otherwise specified by the purchaser, shall consist of a thorough heating at a temperature of not less than 1875 F. (1024 C.), followed by quenching in water or air, depending upon the character of the castings. Intricate castings may require drawing for strain relief which should be done thoroughly at a temperature not in excess of 800 F. (427 C.).

(*c*) Castings intended for heat-resistance applications need not be heat treated, unless specified by the purchaser for purpose of strain relief.

(*d*) This type alloy is intended for use in castings in which the size and design will permit rapid cooling of all parts from the heat-treating temperature (minimum 1875 F. (1024 C.)), to 800 F. (427 C.). For massive or intricate castings, with which it is impracticable to obtain a rate of cooling sufficiently rapid to prevent harmful carbide precipitation, it may be preferable to either introduce stabilizing elements (molybdenum, titanium, columbium or vanadium), or employ a chromium-nickel alloy having a minimum chromium content of 28.0 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.30[a]
Chromium, per cent	23.0 to 27.0
Nickel, per cent	19.0 to 22.0
Manganese, per cent	0.25 to 1.00
Silicon, per cent	0.25 to 1.50
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

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[a] Castings intended for heat-resisting applications may have a carbon content of 0.40 per cent, maximum.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative if requested, and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Physical Properties

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in	72 500
Yield point, min., lb. per sq. in	0.45 tens. str.
Elongation in 2 in., min., per cent	25
Reduction of area, min., per cent	25

(*b*) The yield point shall be determined by the dividers method, using a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. (*a*) Bend tests shall be required for castings only when so specified in the inquiry or order.

(*b*) When a bend test is specified the test specimens shall stand being bent cold through an angle of 90 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

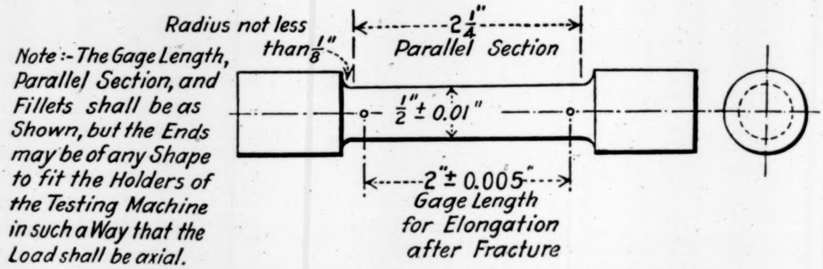
Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 225.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Test Specimens

10. (*a*) Tension and bend test specimens, when required, shall be taken from test bars cast attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service, and where practical, test bars shall be required to be attached to the castings, when so stated in the inquiry or order.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with the corners rounded to a radius not over $\frac{1}{16}$ in.

(*d*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion resistance is usually of prime importance in this alloy, tension tests shall be required only when stated in the inquiry or order. In such cases, one tension test, and when specified, one bend test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

(*d*) If the percentage of elongation of any tension specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and the drawings submitted by the purchaser.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale and injurious defects. Seams, folds, pits, which are other than superficial, and which shall be injurious to the service life of the casting, will be sufficient cause for rejection.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

Marking

15. Where practicable, castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

28 PER CENT CHROMIUM, 9 PER CENT NICKEL ALLOY STEEL CASTINGS[1]

A.S.T.M. Designation: A 173 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.[2]

Scope

1. These specifications cover alloy-steel castings of the 28 per cent chromium, 9 per cent nickel type, for corrosion-resisting and heat-resisting service.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. Unless otherwise specified, heat treatment of the castings shall not be required (Note).

Note.—Intricate castings may require drawing for strain relief which should be done thoroughly at a temperature not to exceed 800 F.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.30[a]
Manganese, per cent	0.25 to 1.00
Silicon, per cent	0.25 to 1.50
Nickel,[b] per cent	8.00 to 10.00
Chromium, per cent	26.00 to 30.00
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

[a] Castings intended for heat-resisting applications may have a carbon content of 0.40 per cent, maximum.

[b] For certain applications, a nickel content within the range of 10 to 12 per cent is desirable.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative if requested, and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting from the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Tension Tests

7. (*a*) The castings (Note) shall conform to the following requirements as to tensile properties (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	85 000
Yield point, min., lb. per sq. in.	0.45 tens. str.
Elongation in 2 in., min., per cent	20
Reduction of area, min., per cent	20

NOTE.—These physical properties refer to the corrosion-resisting alloy having a maximum carbon content of 0.30 per cent. The heat-resisting alloy in the higher range of carbon will indicate lower values for ductility.

(*b*) The yield point shall be determined by the dividers method using a cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. (*a*) Bend tests shall be required only when so specified in the inquiry and order.

(*b*) When a bend test is specified the test specimens shall stand being bent cold through an angle of 90 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 225.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Test Specimens

10. (*a*) Tension and bend test specimens, when required, shall be taken from test bars attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service and where practical, test bars shall be required to be attached to the castings, when so stated in the inquiry and order.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with corners rounded to a radius not over $\frac{1}{16}$ in.

(*d*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since corrosion resistance or heat resistance is usually of prime importance in this alloy, tension tests shall be required only when stated in the inquiry or order. In such cases, one tension test, and when specified, one bend test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

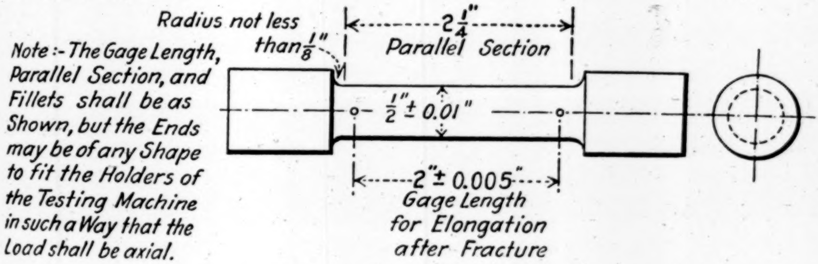
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(*d*) If the percentage of elongation of any test specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

Workmanship

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

14. (*a*) The castings shall be clean and free from any adhering scale. Defects such as seams and folds, which are other than superficial and which are injurious to the service life of the casting will be sufficient cause for rejection.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

Marking

15. Where practicable, castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
20 PER CENT NICKEL, 9 PER CENT CHROMIUM ALLOY STEEL CASTINGS[1]

A.S.T.M. Designation: A 174 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.[2]

Scope

1. These specifications cover alloy-steel castings of the 20 per cent nickel, 9 per cent chromium type, for corrosion-resisting and heat-resisting service.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. (*a*) All castings shall receive a heat treatment proper to their design.

(*b*) Heat treatment, unless otherwise specified by the purchaser, shall consist of a thorough heating of the castings at a temperature not less than 1900 F. (1038 C.), followed by quenching in water or air, depending upon the character of the castings. Where the sections are too heavy for air quenching, and water quenching is too drastic, oil quenching may be employed. Intricate castings may require drawing for strain relief, which should be done thoroughly, at a temperature not in excess of 800 F. (427 C.).

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.20[a]
Chromium, per cent	8.00 to 10.00
Nickel, per cent	19.00 to 22.00
Silicon, per cent	0.25 to 2.00
Manganese, per cent	0.25 to 1.00
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

[a] Castings intended for heat-resisting applications may have a carbon content of 0.35 per cent, maximum.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 4.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Tension Tests

7. (*a*) The castings shall conform to the following requirements as to tensile properties (see Section 10 (*a*)):

Tensile strength, min., lb. per sq. in	65 000
Yield point, min., lb. per sq. in	30 000
Elongation in 2 in., min., per cent	30
Reduction of area, min., per cent	35

(*b*) The yield point shall be determined by the dividers method, using cross-head speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. (*a*) Bend tests shall be required for castings only when so specified in the inquiry and order.

(*b*) When a bend test is specified, the test specimen shall stand being bent cold through an angle of 120 deg. around a pin 1 in. in diameter without cracking on the outside of the bent portion.

Test Specimens

9. (*a*) Tension and bend test specimens, when required, shall be taken from test bars cast attached to special blocks, a sufficient number of which shall be provided for each heat of castings. In the case of castings for unusual or severe service and where practical, test blocks shall be required to be attached to castings, when so stated in the inquiry or order.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests

10. (*a*) Since corrosion resistance is usually of prime importance in this alloy, tension tests shall be required only when stated in the inquiry

or order. In such case, one tension test, and when specified, one bend test shall be required from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

(*c*) If the percentage of elongation of any tension specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

11. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

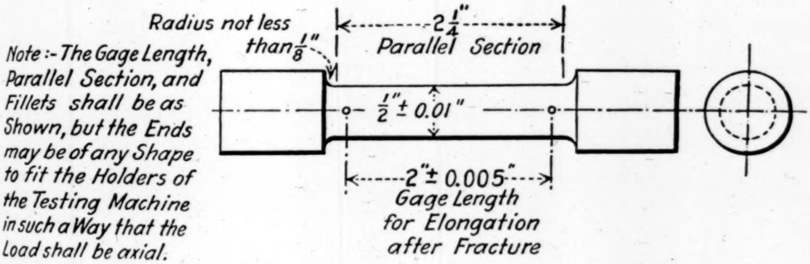
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture
Note :- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Workmanship

12. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

13. (*a*) The castings shall be clean and free from any adhering scale. Defects such as seams, folds, pits, etc., which are other than superficial and which shall be injurious to the service life of the casting will be sufficient cause for rejection.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

Marking

14. Where practicable, castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

17. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

35 PER CENT NICKEL, 15 PER CENT CHROMIUM ALLOY STEEL CASTINGS[1]

A.S.T.M. Designation: A 175 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover alloy-steel castings of the 35 per cent nickel, 15 per cent chromium type (Note).

NOTE.—This alloy has been used for applications requiring strength and scale resistance at elevated temperatures, and also for corrosion resistance at normal and/or high temperatures.

Process

2. The steel shall be made by the electric-furnace process.

Heat Treatment

3. Unless otherwise specified, heat treatment of the castings shall not be required.

Chemical Composition

4. The castings shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.60
Manganese, per cent	0.25 to 1.00
Silicon, per cent	0.50 to 1.75
Nickel, per cent	34.00 to 37.00
Chromium, per cent	14.00 to 17.00
Sulfur, max., per cent	0.050
Phosphorus, max., per cent	0.050

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot poured to represent the heat. The chemical composition thus determined shall be reported to the purchaser or his representative if requested, and shall conform to the requirements specified in Section 4.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Check Analysis

6. Analysis may be made by the purchaser from drillings taken from test bar stubs or from a representative casting for the particular heat required, employing the precaution of obtaining drillings at least $\frac{1}{4}$ in. beneath the surface. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Physical Properties

7. (*a*) The castings shall conform to the following requirements as to tensile properties at room temperature (see Section 11 (*a*)):

Tensile strength, min., lb. per sq. in.	60 000
Yield point, min., lb. per sq. in.	0.45 tens. str.

(*b*) The yield point shall be determined by the dividers method using a crosshead speed not to exceed $\frac{1}{8}$ in. per min. The tensile strength shall be determined at a speed of head not to exceed $1\frac{1}{2}$ in. per min.

Bend Tests

8. Bend tests shall not be required.

Hardness Tests

9. (*a*) The castings shall have a Brinell hardness number not to exceed 185.

(*b*) In making the Brinell hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10) of the American Society for Testing Materials.[1]

Test Specimens

10. (*a*) Tension test specimens shall be taken from test bars attached to separately cast blocks, a sufficient number of which shall be provided for each heat of castings. In case of castings of unusual or severe service and where practical, test bars shall be required to be attached to the castings, when so stated in the inquiry or order.

(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1.

(*c*) Hardness tests shall be made on the castings when practicable, otherwise they shall be made on the bend or tension test specimen.

Number of Tests

11. (*a*) Since heat-resistance is usually of prime importance in this alloy, tension tests shall be required only when stated in the inquiry or order. In such cases, one tension test shall be required from each melt.

(*b*) The average of three Brinell readings shall be taken as the hardness number.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 942.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded, in which case another specimen from the same lot shall be substituted.

Workmanship

12. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish

13. (*a*) The castings shall be clean and free from any adhering scale. Defects, such as seams, folds, etc., which are other than superficial and which are injurious to the service life of the casting, will be sufficient cause for rejection.

Welding

(*b*) Defects which do not impair the strength of the casting for the purpose intended may be welded (after cleaning out to solid metal) by either the electric-arc or the oxyacetylene process. With the electric method, a flux-coated rod is to be used, except in the case of the atomic-hydrogen process, when a bare metal rod may be satisfactorily employed. When the oxyacetylene method is employed, care must be exercised to so control the operation that carbon absorption by the weld metal does not occur. All castings shall be reheat-treated after welding.

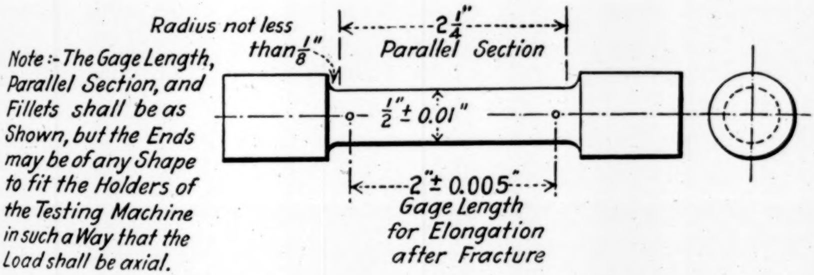
Radius not less than 1/8"
2 1/4"
Parallel Section
Note :- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Marking

14. Where practicable, castings shall be permanently marked by cast symbols or by stamping in such position as not to injure the usefulness of the casting, with the manufacturer's symbol or name, and also a designation to indicate the type or composition of the metal.

Inspection

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of

the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

Rejection

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing

17. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
CORROSION-RESISTING CHROMIUM STEELS (SHEET, STRIP AND PLATE)[1]

A.S.T.M. Designation: A 176 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover soft corrosion-resisting chromium steel sheet, strip and plate. The terms sheet, strip and plate as used in these specifications apply to the following:

Sheet includes products less than $\frac{3}{16}$ in. in thickness and 24 in. and over in width.

Strip includes both hot-rolled and cold-rolled strip as follows:

Cold-Rolled Strip includes material under 24 in. in width.

Hot-Rolled Strip includes material 0.175 in. and less in thickness, and under 24 in. in width.

Plate includes material $\frac{3}{16}$ in. and over in thickness.

Process

2. The steel shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

Discard

3. A sufficient discard shall be made from each ingot to insure freedom from injurious piping and undue segregation.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

	Type	Carbon, max., per cent	Manganese, max., per cent	Sulfur, max., per cent	Phosphorus, max., per cent	Silicon, max., per cent	Chromium, per cent	Nickel, max., per cent
Grade 1	403	0.12	0.60	0.030	0.030	0.75	11.50 to 13.00	0.60
Grade 2	410	0.12	0.60	0.030	0.030	0.75	12.00 to 14.00	0.60
Grade 3	425	0.12	0.60	0.030	0.030	0.75	14.00 to 16.00	0.60
Grade 4	430	0.12	0.50	0.030	0.030	0.75	16.00 to 18.00	0.60
Grade 5	442	0.35	0.50	0.030	0.030	0.75	18.00 to 23.00	0.60
Grade 6	446	0.35	0.50	0.030	0.030	0.75	23.00 to 30.00	0.60
Grade 7	Special	To provide for special properties, variations in chemical composition from that shown in Grades 1 to 6, inclusive, will be permitted.						

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. The analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot made during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. If check analysis is specified by the purchaser, it shall be made from drillings or millings as taken from the finished material or from a broken test specimen. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Physical Properties

7. (*a*) When specified by the purchaser, the material shall conform to the following requirements as to physical properties:

	Tensile Strength, min., lb. per sq. in.	Yield Point, min., lb. per sq. in.	Elongation in 2 in., min., per cent	Brinell Hardness, max.	Rockwell Hardness, max., (B Scale, 100-kg. load, $\frac{1}{16}$-in. ball)	Cold Bend, deg.[b]
Grade 1	70 000	35 000	25.0[a]	202	88	180
Grade 2	70 000	35 000	25.0[a]	202	88	180
Grade 3	70 000	35 000	25.0[a]	202	88	180
Grade 4	70 000	35 000	22.0[a]	202	88	180
Grade 5	75 000	40 000	20.0	202	95	180
Grade 6	75 000	40 000	20.0	217	95	135
Grade 7	Dependent upon the chemical composition specified and to be as mutually agreed upon between the purchaser and the manufacturer.					

[a] Material 0.050 in. and under in thickness (U. S. Standard No. 18 gage and under) shall have a minimum elongation of 20.0 per cent.

[b] See Section 8.

(*b*) The yield point shall be determined by the dividers method.

Bend Tests

8. (*a*) The bend test specimens shall stand being bent cold through the required angle without cracking on the outside of the bent portion.

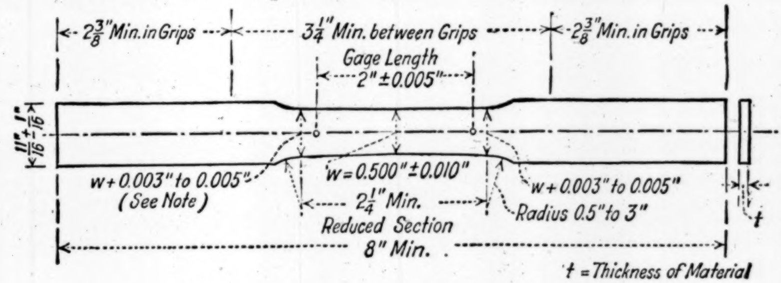
(*b*) Material up to and including $\frac{3}{8}$ in. in thickness shall be bent around a pin the diameter of which is equal to the thickness of the material.

(*c*) Plates over $\frac{3}{8}$ in. in thickness shall be bent around a pin the diameter of which is equal to twice the thickness of the material.

(*d*) Axis of the bends shall be parallel to the direction of rolling.

Test Specimens

9. (*a*) Tension test specimens shall be taken from finished material and shall be in the longitudinal direction. The tension specimens shall be of the full thickness of the material and shall conform to the dimensions shown in Fig. 1, except for plates $\frac{3}{4}$ in. and over in thickness, in which case the test specimens shall be machined to the form and dimensions shown in Fig. 2.

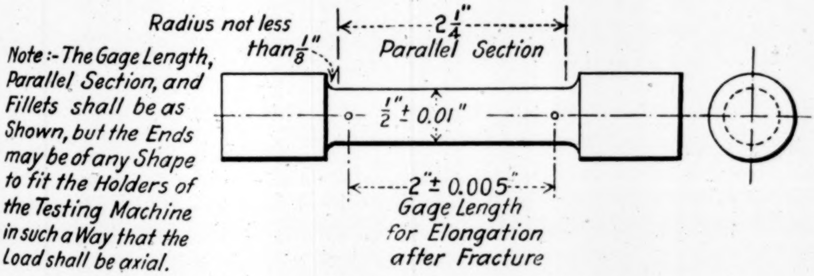


$2\frac{3}{8}$" Min. in Grips
$3\frac{1}{4}$" Min. between Grips
$2\frac{3}{8}$" Min. in Grips
Gage Length
2" ± 0.005"
$\frac{11}{16}$" ± $\frac{1}{16}$"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ± 0.010"
w + 0.003" to 0.005"
$2\frac{1}{4}$" Min.
Reduced Section
Radius 0.5" to 3"
8" Min.
t
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet and Strip Metals.



Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Bend test specimens from sheet and strip less than $\frac{3}{16}$ in. in thickness shall be the full thickness and shall have a width equal to six times the thickness but not less than 1 in. The length shall be equal to the width of the sheet or strip, but in no case longer than 12 in. The edges of the test specimens may be rounded to a radius equal to one-half the thickness.

(*c*) Bend test specimens taken from plates shall be of the full thickness of the material up to and including $\frac{1}{2}$ in. in thickness, of a suitable length, and between 1 and 2 in. in width. The sheared edges shall be removed to a depth of at least $\frac{1}{8}$ in. and the sides shall be smoothed with a file. The corners of the cross-section of the specimen may be broken with a smooth file, but no appreciable rounding of corners will be permitted. In the case of plates over $\frac{1}{2}$ in. in thickness, machined specimens as described in Paragraph (*d*) shall be used.

(*d*) Machined bend test specimens shall be 1 by $\frac{1}{2}$ in. in cross-section and at least 6 in. in length. The edges may be rounded to a $\frac{1}{16}$-in. radius. When permitted by agreement between the purchaser and the manufacturer, the cross-section may be modified to $\frac{1}{2}$-in. square. The center of the cross-section of the test specimen shall be half way between the center and outer surface of the plate, unless otherwise specified.

(*e*) Hardness tests may be made on the ends of the tension specimens, as far as possible from the gage length, before they are subjected to the tension test.

Number of Tests

10. Two tension tests, two hardness tests, and one bend test shall be made on each lot of material, a lot consisting of 100 or less each of sheets, strips or plates, and in no case less than 1000 lb. from the same melt of steel and the same specified thickness.

Special Tests

11. If any special tests are required which are thought to be pertinent to the intended application of the material ordered, they shall be as agreed upon between the purchaser and the manufacturer or as specified in the purchase order.

Physical Tests

12. In making physical tests reference should be made to the following methods of test of the American Society for Testing Materials:

(*a*) *Tension Tests.*—Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8).[1]

(*b*) *Brinell Hardness.*—Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10).[2]

(*c*) *Rockwell Hardness.*—Tentative Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18 – 33 T).[3]

Designation of Finish for Sheets

13. The various types of finish procurable on sheet products shall be as follows:

No. 1 Finish.—Hot rolled, annealed and pickled.

No. 2D Finish.—Full finish (Dull).

No. 2B Finish.—Full finish (Bright cold rolled).

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

[2] *Ibid.*, p. 942.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 967 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1377.

No. 4 Finish.—Standard polish, one or both sides.

No. 6 Finish.—Standard polish, Tampico brushed, one or both sides.

TABLE I.—DIMENSIONAL AND WEIGHT TOLERANCES OF STANDARD SHEET.

No. 1 and No. 2 Finishes.
Weight Tolerances Only to Apply on Polished Finishes.

THICKNESS TOLERANCES

Ordered Thickness, in.	Tolerance, Plus or Minus, in.
0.005	0.001
0.006 to 0.007	0.0015
0.008 to 0.0160	0.002
0.0161 to 0.026	0.003
0.027 to 0.040	0.004
0.041 to 0.058	0.005
0.059 to 0.072	0.006
0.073 to 0.083	0.007
0.084 to 0.098	0.008
0.099 to 0.114	0.009
0.115 to 0.130	0.010
0.131 to 0.145	0.012
0.146 to 0.176	0.014

WIDTH AND LENGTH TOLERANCES[a]

Width	Tolerance	
	Plus	Minus
Up to 42 in.	$\frac{1}{16}$ in.	0
42 in. and over	$\frac{1}{8}$ in.	0
Length		
Up to 120 in.	$\frac{1}{16}$ in.	0
120 in. and over	$\frac{1}{8}$ in.	0

WEIGHT TOLERANCES

The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerances:

	Tolerance Actual Weight Over the Estimated Weight[b]
Any item of 5 sheets or less, or any item estimated to weigh 200 lb. or less	10 per cent
Any item of more than 5 sheets, and estimated to weigh more than 200 lb.	$7\frac{1}{2}$ per cent

There is no under tolerance in weight for No. 1 and No. 2 finishes, these finishes being limited in under tolerance only by the permissible variations in thickness. Polished sheets may actually weigh as much as 5 per cent less than the estimated weight.[b]

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[a] Sheet 0.131 in. and over in thickness, regardless of size, may have permissible variations of $\pm\frac{1}{4}$ in. in width and in length, respectively.

[b] For determining estimated weight the following factor shall be used:

Straight chromium stainless steel sheets	41.2 lb. per sq. ft. per inch thickness

No. 7 Finish.—High lustre finish.

No. 8 Finish.—Mirror finish.

Explanation of Finish:

No. 1. For parts which require no further finishing—for oxidation or scale resistance.

No. 2D. Similar to No. 1, except slightly better finish due to cold rolling. For deep-drawn articles which are polished subsequent to fabrication.

No. 2B. Slightly harder temper than No. 1 and No. 2D, hence should not be used for exceptionally difficult deep-drawing work. This finish lends itself better to polishing than No. 1 or No. 2D.

No. 4. For use where a polished finish is demanded. It is used for such equipment as dairy and ice cream tanks, soda fountains, meat packing and food equipment, architectural and building construction, etc.

No. 6. Tampico brushing of the No. 4 finish results in a satin finish with lower reflectivity than No. 4 finish. For building construction and ornamentation where a brighter finish is undesirable—for use in conjunction with bright finish No. 4, No. 7 and No. 8 as contrasts.

No. 7. The buffing of No. 4 finish results in a sheet with a high degree of lustre, but in which all the grit lines are not removed. It is used for trim for cabinets—for a contrast with other finishes.

TABLE II.—THICKNESS TOLERANCES OF COLD-ROLLED STRIP.

Thickness tolerances are based on measurements taken $\frac{3}{8}$ in. in from the edge on cold-rolled strip 1 in. or over in width, and at any place on the strip on material less than 1 in. in width.

Tolerances given are in inches and all are plus or minus.

Ordered Thickness, in.	Width									
	Under $\frac{1}{2}$ to $\frac{3}{16}$ in., incl.	Under 1 to $\frac{1}{2}$ in., incl.	Under $1\frac{1}{2}$ to 1 in., incl.	Under 3 to $1\frac{1}{2}$ in., incl.	3 to 6 in., incl.	Over 6 to 9 in., incl.	Over 9 to 12 in., incl.	Over 12 to 16 in., incl.	Over 16 to 20 in., incl.	20 to $23\frac{15}{16}$ in., incl.
0.249 to 0.161, incl.	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.005	0.006	0.006
0.160 to 0.100, incl.	0.002	0.002	0.002	0.002	0.003	0.004	0.004	0.004	0.005	0.005
0.099 to 0.069, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004
0.068 to 0.050, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004
0.049 to 0.040, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.004	0.004
0.039 to 0.035, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.003	0.003
0.034 to 0.032, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.031 to 0.029, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.028 to 0.026, incl.	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002	0.002	0.0025	0.003
0.025 to 0.023, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.022 to 0.020, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.019 to 0.017, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.002	0.002	0.002
0.016 to 0.015, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.014 to 0.013, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.012	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.0015
0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015
0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015
0.009 to 0.006, incl.	0.00075	0.00075	0.00075	0.00075	0.00075	......	......	......	......	......
Under 0.006	0.00050	0.00050	0.00050	0.00050	0.00050	......	......	......	......	......

No. 8. The highest degree of polish commercially available. Grit lines and scratches have been removed. This finish is suitable for press plates as used in the laminated paper and fibrous products industry—for mirrors and reflectors.

Designation of Finish for Strip

14. The various types of finish procurable on strip products shall be as follows:

(*a*) *Cold-Rolled Strip:*

No. 1 Finish.—Annealed and pickled.

No. 2 Finish.—Annealed, pickled and rerolled.

No. 3 Finish.—Annealed, pickled, mechanically cleaned or buffed without the use of abrasives.

(*b*) *Hot-Rolled Strip:*

No. 1 Finish.—Hot rolled, annealed and pickled.

Explanation of Finish:

No. 1. For parts requiring maximum amount of deep drawing, for oxidation resistance.

No. 2. Slightly harder temper than No. 1 or No. 3, finish due to extra cold rolling. Very good surface.

No. 3. For parts requiring medium amount of deep drawing, for rolling and molding operations. This strip has a bright surface and requires very little polishing to finish.

Designation of Finish for Plates

15. The various types of finish procurable on plates shall be as follows:

No. 1 Finish.—Hot rolled, annealed and either pickled or sand blasted and pickled.

No. 4 Finish.—Standard polish (limitation on width).

Sheet Tolerances

16. The material referred to as sheet shall conform to the dimensional and weight tolerances indicated in Table I.

Strip Tolerances

17. (*a*) *Cold-Rolled Strip.*—The material referred to as cold-rolled strip shall conform to the dimensional tolerances indicated in Tables II and III.

(*b*) *Hot-Rolled Strip.*—The material referred to as hot-rolled strip shall conform to the dimensional tolerances indicated in Table IV.

Plate Tolerances

18. The material referred to as plate shall conform to the thickness and weight tolerances indicated in Table V.

Finish

19. The material shall be free from injurious defects, shall have a workmanlike appearance, and shall correspond to the designated finish as indicated in Sections 13, 14 and 15.

Inspection

20. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications except when an agreement has previously been made between the manufacturer and purchaser regarding the cost of such tests. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE III.—DIMENSIONAL TOLERANCES OF COLD-ROLLED STRIP.

WIDTH TOLERANCES, NOS. 1, 5, AND 6 EDGES

Edge	Edge Description	Width, in.	Thickness, in.	Tolerance in Width, plus or minus, in.
No. 1	Round or square edge, rolled	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 1		Over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 1		Over $\frac{3}{4}$ to 5, incl	$\frac{1}{8}$ or under	0.005
No. 5	Square rolled or filed after slitting	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 5		Over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 5		Over $\frac{3}{4}$ to 5, incl	$\frac{1}{8}$ or under	0.005
No. 5		Over 5 to 9, incl	$\frac{1}{8}$ to 0.008, incl	0.010
No. 5		Over 9 to 20, incl	0.105 to 0.015	0.010
No. 5		Over 20 to $23\frac{15}{16}$, incl	0.080 to 0.023	0.015
No. 6	Square edge, rolled	$\frac{1}{2}$ or under	$\frac{3}{16}$ or under	0.010
No. 6		Over $\frac{1}{2}$ to $\frac{15}{16}$, incl	$\frac{3}{16}$ to 0.025, incl	$\frac{1}{64}$
No. 6		Over $\frac{15}{16}$ to 2, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{1}{32}$
No. 6		Over 2 to 6, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{3}{64}$

LENGTH TOLERANCES

Length, ft.	Tolerance, in.
Up to 5, incl	$+\frac{3}{8}$
Over 5 to 10, incl	$+\frac{1}{2}$
Over 10 to 20, incl	$+\frac{5}{8}$
Over 20 to 30, incl	$+\frac{3}{4}$
Over 30 to 40, incl	+1
Over 40 to 60, incl	$+1\frac{1}{2}$
Over 60 to 90, incl	+2
Over 90 to 200, incl	$+2\frac{1}{2}$

WIDTH TOLERANCES[a]

Thickness, in.	Widths			
	Up to 2 in.	Over 2 to 6 in.	Over 6 to 12 in.	Over 12 to 24 in., excl.
0.050 or under	0.007	0.010	0.015	0.015
0.051 to 0.083	0.010	0.012	0.015	0.020
0.084 or over	0.012	0.015	0.018	0.020

CAMBER TOLERANCES[b]

Up to and including $1\frac{1}{2}$ in. in width	$\frac{1}{2}$ in. in any 8-ft. length
Over $1\frac{1}{2}$ to 24 in. excl., in width	$\frac{1}{4}$ in. in any 8-ft. length

[a] Width tolerances shown are plus or minus. If variation is desired all one way, double the figure indicated.

[b] Camber shall be determined by placing an 8-ft. straight edge against the concave side of the strip.

TABLE IV.—DIMENSIONAL TOLERANCES OF HOT-ROLLED STRIP.

THICKNESS TOLERANCES

Thickness	Width			
	5 in. and Under	Over 5 to 10 in., incl.	Over 10 to 15 in., incl.	Over 15 to $23\frac{15}{16}$ in., incl.
No. 23 to No. 18, incl........	+0.003 in. −0.003 in.	+0.004 in. −0.004 in.	....	....
No. 17 to No. 11, incl........	+0.004 in. −0.004 in.	+0.005 in. −0.005 in.	+0.006 in. −0.006 in.	+0.007 in. −0.007 in.
No. 10 to 0.187 in., incl......	+0.005 in. −0.005 in.	+0.006 in. −0.006 in.	+0.007 in. −0.007 in.	+0.008 in. −0.008 in.
0.188 to 0.249 in., incl.......	+0.006 in. −0.006 in.	+0.007 in. −0.007 in.	+0.008 in. −0.008 in.	+0.009 in. −0.009 in.

Thickness measurement shall be taken $\frac{3}{8}$ in. from edge of strip.

Tolerance for thickness at center measurement shall be that for the edge measurement plus:

0.001 in. for widths $\frac{1}{2}$ to $1\frac{1}{2}$ in.
0.002 in. for widths $1\frac{1}{2}$ to $2\frac{1}{2}$ in.
0.003 in. for widths $2\frac{1}{2}$ to 5 in.
0.004 in. for widths 5 to 10 in.
0.005 in. for widths 10 to 15 in.
0.006 in. for widths 15 to $23\frac{15}{16}$ in.

WIDTH TOLERANCES

Width, in.	Tolerance, in.	
	Plus	Minus
Up to 1 in. by No. 16 B.w.g. and heavier......	$\frac{1}{32}$	$\frac{1}{32}$
Up to 1 in. by No. 17 B.w.g. and lighter......	$\frac{1}{32}$	$\frac{1}{32}$
Over 1 to 2, incl......	$\frac{1}{32}$	$\frac{1}{32}$
Over 2 to 5, incl......	$\frac{3}{64}$	$\frac{3}{64}$
Over 5 to 10, incl......	$\frac{1}{16}$	$\frac{1}{16}$
Over 10 to 15, incl......	$\frac{3}{32}$	$\frac{3}{32}$
Over 15 to 20, incl......	$\frac{1}{8}$	$\frac{1}{8}$
Over 20 to $23\frac{15}{16}$, incl......	$\frac{5}{32}$	$\frac{5}{32}$

LENGTH TOLERANCES

Length of Strip, ft.	Up to 3 in. in Width		Over 3 Up to 6 in. in Width		Over 6 in. in Width	
	Plus	Minus	Plus	Minus	Plus	Minus
Up to 5, incl......	$\frac{1}{4}$ in.	0	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0
Over 5 to 10, incl......	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0	$\frac{3}{4}$ in.	0
Over 10 to 20, incl......	$\frac{1}{2}$ in.	0	$\frac{5}{8}$ in.	0	1 in.	0
Over 20 to 30, incl......	$\frac{3}{4}$ in.	0	$\frac{3}{4}$ in.	0	$1\frac{1}{4}$ in.	0
Over 30 to 40, incl......	1 in.	0	1 in.	0	$1\frac{1}{2}$ in.	0
Over 40......	$1\frac{1}{2}$ in.	0	$1\frac{1}{2}$ in.	0	$1\frac{3}{4}$ in.	0

CAMBER TOLERANCE

Strip shall be as straight as practicable and not more than $\frac{1}{4}$ in. out of line in any 8 ft. of length, with camber measurement taken on the concave edge.

Rejection

21. (*a*) Unless otherwise specified, any rejection based on tests in accordance with these specifications shall be reported within 10 days from date of test.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works shall be rejected and the manufacturer shall be notified.

TABLE V.—STANDARD ROLLING TOLERANCES OF PLATES.

THICKNESS TOLERANCES[a]

All plates must be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. under the thickness ordered, and the overweight of each lot[b] in each shipment shall not exceed the amount given in the table below.

WEIGHT TOLERANCES[c]

Ordered thickness, in.	Permissible Excess in Average Weight per Square Foot of Plates for Widths Given, Expressed in Percentage of Nominal Weight								
	Under 48 in.	48 in., incl., to 60 in., excl.	60 in., incl., to 72 in., excl.	72 in., incl., to 84 in., excl.	84 in., incl., to 96 in., excl.	96 in., incl., to 108 in., excl.	108 in., incl., to 120 in., excl.	120 in., incl., to 132 in., excl.	132 in., incl., to 144 in., excl.
$\frac{3}{16}$, incl., to $\frac{1}{4}$, excl.	10.5	12	13.5	15	18	....	....	....	....
$\frac{1}{4}$, incl., to $\frac{5}{16}$, excl.	9	10.5	12	13.5	15	18	21	24	28.5
$\frac{5}{16}$, incl., to $\frac{3}{8}$, excl.	7.5	9	10.5	12	13.5	15	18	21	25.5
$\frac{3}{8}$, incl., to $\frac{7}{16}$, excl.	7	7.5	9	10.5	12	13.5	15	18	22.5
$\frac{7}{16}$, incl., to $\frac{1}{2}$, excl.	6	7	7.5	9	10.5	12	13.5	15	19.5
$\frac{1}{2}$, incl., to $\frac{5}{8}$, excl.	5.5	6	7	7.5	9	10.5	12	13.5	16.5
$\frac{5}{8}$, incl., to $\frac{3}{4}$, excl.	4.5	5.5	6	7	7.5	9	10.5	12	13.5
$\frac{3}{4}$, incl., to 1, excl.	4	4.5	5.5	6	7	7.5	9	10.5	12
1, or over	4	4	4.5	5.5	6	7	7.5	9	10.5

[a] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. under the specified thickness.

[b] The term "lot" means all of the plates of each group width and each group thickness.

[c] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount given in the above table.

Rehearing

22. Samples tested in accordance with these specifications, which represent rejected material, shall be preserved three weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
CORROSION-RESISTING CHROMIUM-NICKEL STEELS (SHEET, STRIP AND PLATE)[1]

A.S.T.M. Designation: A 167 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover soft corrosion-resisting chromium-nickel steel sheet, strip and plate. The terms sheet, strip and plate as used in these specifications apply to the following:

Sheet includes products less than $\frac{3}{16}$ in. in thickness and 24 in. and over in width.

Strip includes both hot-rolled and cold-rolled strip as follows:

Cold-Rolled Strip includes material under 24 in. in width.

Hot-Rolled Strip includes material 0.175 in. and less in thickness and under 24 in. in width.

Plate includes material $\frac{3}{16}$ in. and over in thickness.

MANUFACTURE

Process

2. The steel shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

Discard

3. A sufficient discard shall be made from each ingot to insure freedom from injurious piping and undue segregation.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

	Type No.	Carbon, per cent	Manganese, max., per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, max., per cent	Chromium, min., per cent	Nickel, min., per cent
Grade 1	302	0.08 to 0.20	0.60	0.035	0.030	0.75	17.0	7.0
Grade 2	304	0.08 max.	0.60	0.035	0.030	0.75	17.0	7.0
Grade 3	305	0.08 to 0.20	0.60	0.035	0.030	0.75	18.0	8.0
Grade 4	306	0.08 max.	0.60	0.035	0.030	0.75	18.0	8.0
Grade 5[a]	320	0.08 max.	0.60	0.035	0.030	0.75	17.0	7.0
Grade 6[b]	316	0.08 max.	1.50	0.035	0.030	0.75	17.0	7.0
Grade 7	309	0.30 max.	1.50	0.035	0.030	2.00	23.0	11.0
Grade 8	310	0.30 max.	1.50	0.035	0.030	2.00	23.0	17.0

[a] Grade 5 shall have a minimum Titanum content of four times the carbon content.
[b] Grade 6 shall have a Molybdenum content of 2.00 to 4.00 per cent.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. The analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. If check analysis is specified by the purchaser, it shall be made from drillings or millings as taken from the finished material or from a broken test specimen. The chemical composition thus determined shall conform to the requirements specified in Section 4.

PHYSICAL PROPERTIES AND TESTS

7. (*a*) When specified by the purchaser, the material shall conform to the following requirements as to physical properties:

	Tensile Strength, min., lb. per sq. in.	Yield Point min., lb. per sq. in.	Elongation in 2 in., min., per cent	Hardness		Cold Bend,[a] deg.
				Brinell, max.	Rockwell (B Scale, 100-kg. load, $\frac{1}{16}$-in. ball), max.	
Grade 1	80 000	30 000	40.0	202	88	180
Grade 2	80 000	30 000	40.0	202	88	180
Grade 3	80 000	30 000	40.0	202	88	180
Grade 4	80 000	30 000	40.0	202	88	180
Grade 5	80 000	35 000	40.0	202	88	180
Grade 6	85 000	40 000	40.0	217	95	180
Grade 7	90 000	40 000	40.0	217	95	180
Grade 8	90 000	40 000	40.0	217	95	180

[a] See Section 8.

(*b*) The yield point shall be determined by the dividers method.

Bend Tests

8. (*a*) The bend test specimens shall stand being bent cold through the required angle without cracking on the outside of the bent portion.

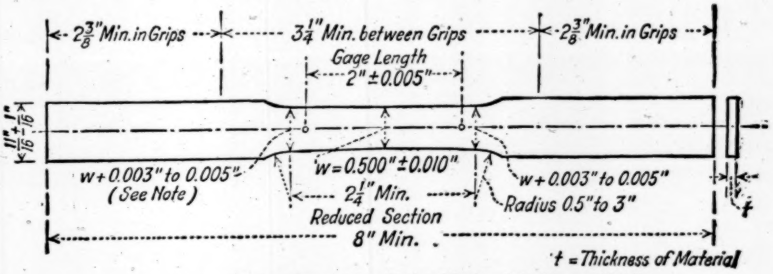
(*b*) Material up to and including $\frac{3}{8}$ in. in thickness shall be bent around a pin the diameter of which is equal to the thickness of the material.

(*c*) Plates $\frac{3}{8}$ in. and over in thickness shall be bent around a pin the diameter of which is equal to twice the thickness of the material.

(*d*) Axis of the bends shall be parallel to the direction of rolling.

Test Specimens

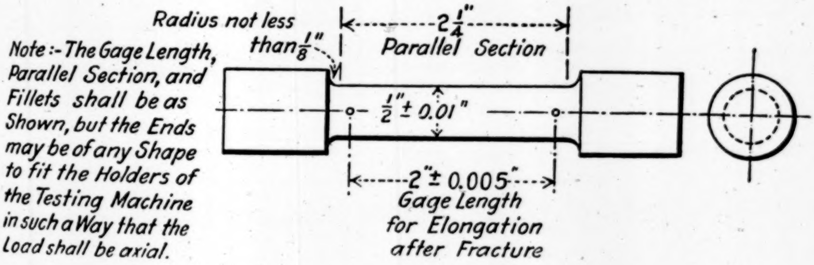
9. (*a*) Tension test specimens shall be taken from finished material and shall be in the longitudinal direction. The tension specimens shall be of the full thickness of the material and shall conform to the dimensions shown in Fig. 1, except for plates $\frac{3}{4}$ in. and over in thickness, in which case the test specimens shall be machined to the form and dimensions shown in Fig. 2.


$2\frac{3}{8}$" Min. in Grips
$3\frac{1}{4}$" Min. between Grips
$2\frac{3}{8}$" Min. in Grips
Gage Length
2" ±0.005"
$\frac{11}{16}$" ± $\frac{1}{16}$"
w + 0.003" to 0.005"
(See Note)
w = 0.500" ±0.010"
$2\frac{1}{4}$" Min.
Reduced Section
w + 0.003" to 0.005"
Radius 0.5" to 3"
8" Min.
t
t = Thickness of Material

Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet and Strip Metals.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.—Standard 2-in. Gage Length Tension Test Specimen.

(*b*) Bend test specimens from sheet and strip less than $\frac{3}{16}$ in. in thickness shall be the full thickness and shall have a width equal to six times the thickness but not less than 1 in. The length shall be equal to the width of the sheet or strip, but in no case longer than 12 in. The edges of the test specimens may be rounded to a radius equal to one-half the thickness.

(*c*) Bend test specimens taken from plates shall be of the full thickness of the material up to and including $\frac{1}{2}$ in. in thickness, of a suitable length, and between 1 and 2 in. in width. The sheared edges shall be removed to a depth of at least $\frac{1}{8}$ in. and the sides shall be smoothed with a file. The corners of the cross-section of the specimen may be broken with a smooth file, but no appreciable rounding of corners will be permitted. In the case of plates over ½ in. in thickness, machined specimens as described in Paragraph (*d*) shall be used.

(*d*) Machined bend test specimens shall be 1 by ½ in. in cross-section and at least 6 in. in length. The edges may be rounded to a $\frac{1}{16}$-in. radius. When permitted by agreement between the purchaser and the manufacturer, the cross-section may be modified to ½-in. square. The center of the cross-section of the test specimen shall be half way between the center and outer surface of the plate, unless otherwise specified.

(*e*) Hardness tests may be made on the ends of the tension specimens, as far as possible from the gage length, before they are subjected to the tension test.

Number of Tests

10. Two tension tests, two hardness tests and one bend test shall be taken from each lot of material, a lot consisting of 100 or less each of sheets, strips or plates, and in no case less than 1000 lb. from the same melt of steel and the same specified thickness.

Special Tests

11. If any special tests are required which are thought to be pertinent to the intended application of the material ordered, they shall be as agreed upon between the purchaser and the manufacturer.

Physical Tests

12. In making physical tests reference should be made to the following methods of test of the American Society for Testing Materials:

(*a*) *Tension Tests.*—Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8).[1]

(*b*) *Brinell Hardness.*—Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10).[2]

(*c*) *Rockwell Hardness.*—Tentative Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18 – 33 T).[3]

FINISH

Designation of Finish for Sheets

13. The various types of finish procurable on sheet products shall be as follows:

No. 1. Hot rolled, annealed and pickled.
No. 2D. Full finish (Dull).
No. 2B. Full finish (Bright cold rolled).
No. 4. Standard polish, one or both sides.
No. 6. Standard polish, Tampico brushed, one or both sides.
No. 7. High lustre finish.
No. 8. Mirror finish.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

[2] *Ibid.*, p. 942.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 967 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1377.

Explanation of Finish:

No. 1. For parts which require no further finishing—for oxidation or scale resistance.

No. 2D. Similar to No. 1, except slightly better finish due to cold rolling. For deep-drawn articles which are polished subsequent to fabrication.

No. 2B. Slightly harder temper than No. 1 and No. 2D, hence should not be used for exceptionally difficult deep-drawing work. This finish lends itself better to polishing than No. 1 or No. 2D.

TABLE I.—DIMENSIONAL AND WEIGHT TOLERANCES OF STANDARD SHEET.

No. 1 and No. 2 Finishes.
Weight Tolerances Only to Apply on Polished Finishes.

THICKNESS TOLERANCES

Ordered Thickness, in.	Tolerance, Plus or Minus, in.
0.005	0.001
0.006 to 0.007	0.0015
0.008 to 0.0160	0.002
0.0161 to 0.026	0.003
0.027 to 0.040	0.004
0.041 to 0.058	0.005
0.059 to 0.072	0.006
0.073 to 0.083	0.007
0.084 to 0.098	0.008
0.099 to 0.114	0.009
0.115 to 0.130	0.010
0.131 to 0.145	0.012
0.146 to 0.176	0.014

WIDTH AND LENGTH TOLERANCES[a]

Width	Tolerance	
	Plus	Minus
Up to 42 in.	$\frac{1}{16}$ in.	0
42 in. and over	$\frac{1}{8}$ in.	0
Length		
Up to 120 in.	$\frac{1}{16}$ in.	0
120 in. and over	$\frac{1}{8}$ in.	0

WEIGHT TOLERANCES

The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerances:

	Tolerance Actual Weight Over the Estimated Weight[b]
Any item of 5 sheets or less, or any item estimated to weigh 200 lb. or less	10 per cent
Any item of more than 5 sheets, and estimated to weigh more than 200 lb.	$7\frac{1}{2}$ per cent

There is no under tolerance in weight for No. 1 and No. 2 finishes, these finishes being limited in under tolerance only by the permissible variations in thickness. Polished sheets may actually weigh as much as 5 per cent less than the estimated weight.[b]

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[a] Sheet 0.131 in. and over in thickness, regardless of size, may have permissible variations of $\pm\frac{1}{4}$ in. in width and in length, respectively.

[b] For determining estimated weight the following factor shall be used:
Chromium-nickel stainless steel sheets ..... 42.0 lb. per sq. ft. per inch thickness

No. 4. For use where a polished finish is demanded. It is used for such equipment as dairy and ice cream tanks, soda fountains, meat packing and food equipment, architectural and building construction, etc.

No. 6. Tampico brushing of the No. 4 finish results in a satin finish with lower reflectivity than No. 4 finish. For building construction and ornamentation where a brighter finish is undesirable—for use in conjunction with bright finish No. 4, No. 7 and No. 8 as contrasts.

No. 7. The buffing of No. 4 finish results in a sheet with a high degree of lustre, but in which all the grit lines are not removed. It is used for trim for cabinets—for a contrast with other finishes.

No. 8. The highest degree of polish commercially available. Grit lines and scratches have been removed. This finish is suitable for press plates as used in the laminated paper and fibrous products industry—for mirrors and reflectors.

Designation of Finish for Strip

14. The various types of finish procurable on strip products shall be as follows:

(*a*) *Cold-Rolled Strip:*

No. 1. Annealed and pickled.

No. 2. Annealed, pickled and rerolled.

No. 3. Annealed, pickled, mechanically cleaned or buffed without the use of abrasives.

TABLE II.—THICKNESS TOLERANCES OF COLD-ROLLED STRIP.

Thickness tolerances are based on measurements taken $\frac{3}{8}$ in. in from the edge on cold-rolled strip 1 in. or over in width, and at any place on the strip on material less than 1 in. in width.

Tolerances given are in inches and all are plus or minus.

Ordered Thickness, in.	Width									
	Under $\frac{1}{2}$ to $\frac{3}{16}$ in., incl.	Under 1 to $\frac{1}{2}$ in., incl.	Under $1\frac{1}{2}$ to 1 in., incl.	Under 3 to $1\frac{1}{2}$ in., incl.	3 to 6 in., incl.	Over 6 to 9 in., incl.	Over 9 to 12 in., incl.	Over 12 to 16 in., incl.	Over 16 to 20 in., incl.	20 to $23\frac{15}{16}$ in., incl.
0.249 to 0.161, incl.	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.005	0.006	0.006
0.160 to 0.100, incl.	0.002	0.002	0.002	0.002	0.003	0.004	0.004	0.004	0.005	0.005
0.099 to 0.069, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004
0.068 to 0.050, incl.	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004
0.049 to 0.040, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.004	0.004
0.039 to 0.035, incl.	0.002	0.002	0.002	0.002	0.0025	0.003	0.003	0.003	0.003	0.003
0.034 to 0.032, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.031 to 0.029, incl.	0.0015	0.0015	0.0015	0.0015	0.002	0.0025	0.0025	0.0025	0.003	0.003
0.028 to 0.026, incl.	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002	0.002	0.0025	0.003
0.025 to 0.023, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.022 to 0.020, incl.	0.001	0.001	0.001	0.001	0.0015	0.002	0.002	0.002	0.0025	0.0025
0.019 to 0.017, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.002	0.002	0.002
0.016 to 0.015, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.014 to 0.013, incl.	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.002	0.002
0.012	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015	0.0015
0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015	0.0015
0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0015	0.0015
0.009 to 0.006, incl.	0.00075	0.00075	0.00075	0.00075	0.00075	......	......	......	......	......
Under 0.006	0.00050	0.00050	0.00050	0.00050	0.00050	......	......	......	......	......

(*b*) *Hot-Rolled Strip:*

No. 1. Hot rolled, annealed and pickled.

Explanation of Finish:

No. 1. For parts requiring maximum amount of deep drawing, for oxidation resistance.

No. 2. Slightly harder temper than No. 1 or No. 3, finish due to extra cold rolling. Very good surface.

No. 3. For parts requiring medium amount of deep drawing, for rolling and molding operations. This strip has a bright surface and requires very little polishing to finish.

Designation of Finish for Plates

15. The various types of finish procurable on plates shall be as follows:

No. 1. Hot rolled, annealed and either pickled or sand blasted and pickled.

No. 4. Standard polish (limitation on width).

PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT

Sheet Tolerances

16. The material referred to as sheet shall conform to the dimensional and weight tolerances indicated in Table I.

TABLE III.—DIMENSIONAL TOLERANCES OF COLD-ROLLED STRIP.

WIDTH TOLERANCES, NOS. 1, 4, 5, AND 6 EDGES

Edge	Edge Description	Width, in.	Thickness, in.	Tolerance in Width, plus or minus, in.
No. 1	Round or square edge, rolled	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 1		over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 1		over $\frac{3}{4}$ to 5, incl.	$\frac{1}{8}$ or under	0.005
No. 5	Square rolled or filed after slitting	$\frac{9}{32}$ or under	$\frac{1}{16}$ or under	0.005
No. 5		over $\frac{9}{32}$ to $\frac{3}{4}$, incl	$\frac{3}{32}$ or under	0.005
No. 5		over $\frac{3}{4}$ to 5, incl	$\frac{1}{8}$ or under	0.005
No. 5		over 5 to 9, incl	$\frac{1}{8}$ to 0.008, incl	0.010
No. 5		over 9 to 20, incl	0.105 to 0.015	0.010
No. 5		over 20 to 23$\frac{15}{16}$, incl	0.080 to 0.023	0.015
No. 6	Square edge, rolled	$\frac{1}{2}$ or under	$\frac{3}{16}$ or under	0.010
No. 6		over $\frac{1}{2}$ to $\frac{15}{16}$, incl	$\frac{3}{16}$ to 0.025, incl	$\frac{1}{64}$
No. 6		over $\frac{15}{16}$ to 2, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{1}{32}$
No. 6		over 2 to 6, incl	$\frac{1}{4}$ to 0.025, incl	$\frac{3}{64}$

LENGTH TOLERANCES

Length, ft.	Tolerance, in.
Up to 5, incl	$+\frac{3}{8}$
Over 5 to 10, incl	$+\frac{1}{2}$
Over 10 to 20, incl	$+\frac{5}{8}$
Over 20 to 30, incl	$+\frac{3}{4}$
Over 30 to 40, incl	+1
Over 40 to 60, incl	$+1\frac{1}{2}$
Over 60 to 90, incl	+2
Over 90 to 200, incl	$+2\frac{1}{2}$

WIDTH TOLERANCES[a]

Thickness, in.	Widths			
	Up to 2 in.	Over 2 to 6 in.	Over 6 to 12 in.	Over 12 to 24 in., excl.
0.050 or under	0.007	0.010	0.015	0.015
0.051 to 0.083	0.010	0.012	0.015	0.020
0.084 or over	0.012	0.015	0.018	0.020

CAMBER TOLERANCES[b]

Up to and including $1\frac{1}{2}$ in. in width	$\frac{1}{2}$ in. in any 8-ft. length
Over $1\frac{1}{2}$ to 24 in. excl., in width	$\frac{1}{4}$ in. in any 8-ft. length

[a] Width tolerances shown are plus or minus. If variation is desired all one way, double the figure indicated.

[b] Camber shall be determined by placing an 8-ft. straight edge against the concave side of the strip.

Strip Tolerances

17. (*a*) *Cold-Rolled Strip.*—The material referred to as cold-rolled strip shall conform to the dimensional tolerances indicated in Tables II and III.

(*b*) *Hot-Rolled Strip.*—The material referred to as hot-rolled strip shall conform to the dimensional tolerances indicated in Table IV.

TABLE IV.—DIMENSIONAL TOLERANCES OF HOT-ROLLED STRIP.

THICKNESS TOLERANCES

Thickness	Width			
	Up to 5 in., incl.	Over 5 in. to 10 in., incl.	Over 10 in. to 15 in., incl.	Over 15 in. to 23$\frac{15}{16}$ in., incl.
No. 23 to No. 18, incl.	+0.003 in.−0.003 in.	+0.004 in.−0.004 in.	....	....
No. 17 to No. 11, incl.	+0.004 in.−0.004 in.	+0.005 in.−0.005 in.	+0.006 in.−0.006 in.	+0.007 in.−0.007 in.
No. 10 to 0.187 in., incl.	+0.005 in.−0.005 in.	+0.006 in.−0.006 in.	+0.007 in.−0.007 in.	+0.008 in.−0.008 in.
0.188 to 0.249 in., incl.	+0.006 in.−0.006 in.	+0.007 in.−0.007 in.	+0.008 in.−0.008 in.	+0.009 in.−0.009 in.

Thickness measurement shall be taken $\frac{3}{8}$ in. from edge of strip.

Tolerance for thickness at center measurement shall be that for the edge measurement plus:

0.001 in. for widths $\frac{1}{2}$ to 1$\frac{1}{2}$ in.
0.002 in. for widths 1$\frac{1}{2}$ to 2$\frac{1}{2}$ in.
0.003 in. for widths 2$\frac{1}{2}$ to 5 in.
0.004 in for widths 5 to 10 in.
0.005 in. for widths 10 to 15 in.
0.006 in. for widths 15 to 23$\frac{15}{16}$ in.

WIDTH TOLERANCE

Width, in.	Tolerance, in.	
	Plus	Minus
Up to 1 in. by No. 16 B.w.g. and heavier	$\frac{1}{32}$	$\frac{1}{32}$
Up to 1 in. by No. 17 B.w.g. and lighter	$\frac{1}{32}$	$\frac{1}{32}$
Over 1 to 2, incl.	$\frac{1}{32}$	$\frac{1}{32}$
Over 2 to 5, incl.	$\frac{3}{64}$	$\frac{3}{64}$
Over 5 to 10, incl.	$\frac{1}{16}$	$\frac{1}{16}$
Over 10 to 15, incl.	$\frac{3}{32}$	$\frac{3}{32}$
Over 15 to 20, incl.	$\frac{1}{8}$	$\frac{1}{8}$
Over 20 to 23$\frac{15}{16}$, incl.	$\frac{5}{32}$	$\frac{5}{32}$

LENGTH TOLERANCE

Length of Strip, ft.	Up to 3 in. in Width		Over 3 Up to 6 in. in Width		Over 6 in. in Width	
	Plus	Minus	Plus	Minus	Plus	Minus
Up to 5, incl.	$\frac{1}{4}$ in.	0	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0
Over 5 to 10, incl.	$\frac{3}{8}$ in.	0	$\frac{1}{2}$ in.	0	$\frac{3}{4}$ in.	0
Over 10 to 20, incl.	$\frac{1}{2}$ in.	0	$\frac{5}{8}$ in.	0	1 in.	0
Over 20 to 30, incl.	$\frac{3}{4}$ in.	0	$\frac{3}{4}$ in.	0	1$\frac{1}{4}$ in.	0
Over 30 to 40, incl.	1 in.	0	1 in.	0	1$\frac{1}{2}$ in.	0
Over 40	1$\frac{1}{2}$ in.	0	1$\frac{1}{2}$ in.	0	1$\frac{3}{4}$ in.	0

CAMBER TOLERANCE

Strip shall be as straight as practicable and not more than $\frac{1}{4}$ in. out of line in any 8 ft. of length, with camber measurement taken on the concave edge.

Plate Tolerances

18. The material referred to as plate shall conform to the thickness and weight tolerances indicated in Table V.

Finish

19. The material shall be free from injurious defects, shall have a workmanlike appearance, and shall correspond to the designated finish as indicated in Sections 13, 14 and 15.

Table V.—Standard Rolling Tolerances of Plates.

Thickness Tolerances[a]

All plates must be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. under the thickness ordered, and the overweight of each lot[b] in each shipment shall not exceed the amount given in the table below.

Weight Tolerances[c]

Ordered Thickness, in.	Permissible Excess in Average Weight per Square Foot of Plates for Widths Given, Expressed in Percentage of Nominal Weight								
	Under 48 in.	48 in., incl., to 60 in., excl.	60 in., incl., to 72 in., excl.	72 in., incl., to 84 in., excl.	84 in., incl., to 96 in., excl.	96 in., incl., to 108 in., excl.	108 in., incl., to 120 in., excl.	120 in., incl., to 132 in., excl.	132 in., incl., to 144 in., excl.
$\frac{3}{16}$, incl., to $\frac{1}{4}$, excl.	10.5	12	13.5	15	18	....	....	....	....
$\frac{1}{4}$, incl., to $\frac{5}{16}$, excl.	9	10.5	12	13.5	15	18	21	24	28.5
$\frac{5}{16}$, incl., to $\frac{3}{8}$, excl.	7.5	9	10.5	12	13.5	15	18	21	25.5
$\frac{3}{8}$, incl., to $\frac{7}{16}$, excl.	7	7.5	9	10.5	12	13.5	15	18	22.5
$\frac{7}{16}$, incl., to $\frac{1}{2}$, excl.	6	7	7.5	9	10.5	12	13.5	15	19.5
$\frac{1}{2}$, incl., to $\frac{5}{8}$, excl.	5.5	6	7	7.5	9	10.5	12	13.5	16.5
$\frac{5}{8}$, incl., to $\frac{3}{4}$, excl.	4.5	5.5	6	7	7.5	9	10.5	12	13.5
$\frac{3}{4}$, incl., to 1, excl.	4	4.5	5.5	6	7	7.5	9	10.5	12
1, or over	4	4	4.5	5.5	6	7	7.5	9	10.5

[a] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. under the specified thickness.

[b] The term "lot" means all of the plates of each group width and each group thickness.

[c] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount given in the above table.

INSPECTION AND REJECTION

Inspection

20. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is in progress to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications except when an agreement has previously been made between the manufacturer and purchaser regarding the cost of such tests.

Rejection

21. (*a*) Unless otherwise specified, any rejection based on tests in accordance with these specifications shall be reported within 10 days from date of test.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works shall be rejected and the manufacturer shall be notified.

Rehearing

22. Samples tested in accordance with this specification, which represent rejected material, shall be preserved three weeks from date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a hearing within that time.

TENTATIVE SPECIFICATIONS
FOR
HIGH-STRENGTH CORROSION-RESISTING CHROMIUM-NICKEL STEELS (SHEET AND STRIP)[1]

A.S.T.M. Designation: A 177 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These specifications cover high-strength corrosion-resisting chromium-nickel steel sheet and strip. The terms sheet and strip as used in these specifications apply to the following:

Sheet includes products less than $\frac{3}{16}$ in. in thickness and 24 in. and over in width.

Strip includes products 0.175 in. and less in thickness and under 24 in. in width.

Process

2. The steel shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

Discard

3. A sufficient discard shall be made from each ingot to insure freedom from injurious piping and undue segregation.

Chemical Composition

4. The steel shall conform to the following requirements as to chemical composition:

Carbon, max., per cent	0.12[a]
Manganese, max., per cent	0.60
Phosphorus, max., per cent	0.035
Sulfur, max., per cent	0.035
Silicon, max., per cent	0.75
Chromium, min., per cent	17.0
Nickel, min., per cent	7.0

[a] For material of three-quarter hard and full hard tempers a carbon content of 0.15 per cent, maximum, is permissible.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Ladle Analysis

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. The analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot made during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis

6. If check analysis is specified by the purchaser, it shall be made from drillings or millings as taken from the finished material or from a broken test specimen. The chemical composition thus determined shall conform to the requirements specified in Section 4.

Temper

7. The various tempers procurable in sheet and strip shall be as indicated in the following table:

Quarter Hard Temper
Half Hard Temper
Three-Quarter Hard Temper
Full Hard Temper

Tension Tests

8. (*a*) When specified by the purchaser, the material shall conform to the following requirements as to physical properties:

TEMPER	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT		
			UP TO 0.015 IN. THICK	0.016 TO 0.030 IN. THICK	0.031 IN. THICK AND OVER
Quarter Hard......	125 000	75 000	25.0	25.0	25.0
Half Hard.........	150 000	110 000	9.0	10.0	10.0
Three-Quarter Hard	175 000	135 000	3.0	5.0	7.0
Full Hard.........	185 000	140 000	3.0	4.0	5.0

(*b*) The yield point shall be determined by the dividers method.

(*c*) In making tension tests reference should be made to the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

Bend Tests

9. (*a*) The bend test specimens shall stand being bent cold through the required angle indicated in the following table, without cracking on the outside of the bent portion:

TEMPER	0.030 IN. THICK AND LESS		0.031 TO 0.050 IN. THICK		0.051 IN. THICK AND OVER	
	ANGLE, DEG.	*N*	ANGLE, DEG.	*N*	ANGLE, DEG.	*N*
Quarter Hard....................	180	1	180	1	90	2
Half Hard.......................	180	2	180	4	90	2
Three-Quarter Hard............	180	4	90	$2\frac{1}{2}$	...	..
Full Hard.......................	180	6	90	$3\frac{1}{2}$	...	..

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

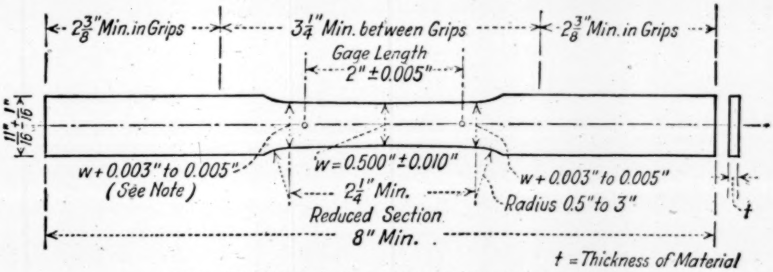
(*b*) One bend test specimen shall be bent in the longitudinal and one in the transverse direction.

(*c*) The radius of the bend shall be equal to "*N*" times the thickness of the specimen. The values for "*N*" are indicated in the table in Paragraph (*a*).

Test Specimens

10. (*a*) Tension test specimens shall be taken from finished material and shall be in the longitudinal direction. The tension specimens shall be of the full thickness of the material and shall conform to the dimensions shown in Fig. 1.

(*b*) Bend test specimens from sheet and strip less than $\frac{3}{16}$ in. in thickness shall be the full thickness of the material. The longitudinal bend test specimen from strip less than 1 in. in width shall be the width of the material. The width of specimens over 1 in. in width shall be six times the thickness but not less than 1 in. When possible, the length shall be at least 6 in. The transverse bend test specimen shall have a width six times the thickness of the material but not less than 1 in. The length shall be equal to the width of the sheet or strip, but in no case longer than 12 in. The edges of the test specimens may be rounded to a radius equal to one-half the thickness.



Note: Gradual Taper from Ends of Reduced Section to Middle.
All Machining Dimensions are Shown below and Testing Dimensions above Specimen.

The ends shall be symmetrical within 0.01 in.

FIG. 1.—Standard Tension Test Specimen for Sheet and Strip Metals.

Number of Tests

11. Two tension tests and two bend tests shall be made on each lot of material, a lot consisting of 100 or less each of sheets or strips, and in no case less than 1000 lb. from the same melt of steel and the same specified thickness.

Special Tests

12. If any special tests are required which are thought to be pertinent to the intended application of the material ordered, they shall be as agreed

upon between the purchaser and the manufacturer or as specified in the purchase order.

Thickness Tolerances

13. (*a*) Material up to 24 in., inclusive, in width shall not vary from the thickness specified by more than ±5 per cent of the ordered thickness, except that in no case shall the minimum thickness tolerance be less than ±0.001 in.

(*b*) For material over 24 in. in width the thickness tolerances shall be as agreed upon between the purchaser and the manufacturer.

(*c*) In determining thickness the material shall be gaged $\frac{3}{8}$ in. from the edge and may be thicker at the crown (center) than at the edge by one-half the thickness tolerance taken one way.

Camber Tolerances

14. (*a*) Material up to and including $1\frac{1}{2}$ in. in width shall not have a camber exceeding $\frac{1}{2}$ in. in 8 ft. or less.

(*b*) Material over $1\frac{1}{2}$ in. in width shall not have a camber exceeding $\frac{1}{4}$ in. in 8 ft. or less.

(*c*) Camber shall be measured by placing a straight edge against the concave edge of the sheet or strip.

Flatness Tolerances

15. (*a*) Material shall not have buckles exceeding the following limits:

0.016 in. and under in thickness	$\frac{1}{4}$ in.
0.016 in. to 0.030 in. in thickness	$\frac{3}{8}$ in.
0.030 in. in thickness and over	$\frac{1}{2}$ in.

(*b*) The height of buckle shall be determined by measuring the distance from a flat surface on which the sheet or strip lies to the maximum rise of the sheet or strip.

Width Tolerances

16. (*a*) *Sheets.*—For non-resquared sheets the width shall not vary more than $\frac{1}{4}$ in. over the ordered size. For resquared sheets the width shall not vary more than $\frac{1}{16}$ in. over the ordered size. No variations under the specified width are permissible.

(*b*) *Strip.*—The width of strip material shall not vary from the specified width by more than $\pm\frac{1}{32}$ in.

Other Tolerances

17. Tolerances closer than or other than those shown in Sections 13 to 16, inclusive, shall be as agreed upon between the purchaser and the manufacturer.

Workmanship and Finish

18. (*a*) The surface finish shall be as cold rolled or as otherwise designated.

(*b*) The material shall be free from injurious defects, shall have a workmanlike appearance and shall correspond to the designated finish as indicated in Paragraph (*a*).

Inspection

19. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications, except when an agreement has previously been made between the manufacturer and purchaser regarding the cost of such tests. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported within ten days from date of test.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works shall be rejected and the manufacturer shall be notified.

Rehearing

21. Samples tested in accordance with these specifications, which represent rejected material, shall be preserved three weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

ELECTRODEPOSITED COATINGS OF ZINC ON STEEL[1]

A.S.T.M. Designation: A 164 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover requirements for electroplated zinc coatings on steel articles that are required to withstand corrosion. Two types of coating (Notes 1 and 2) are covered: namely,

Type LS.—For general service.

Type RS.—For mild service.

NOTE 1: *Explanation of Symbols.*—The initial letters *L* and *R* were adopted as arbitrary designations of grades of plating. The second letter (*S*) refers to steel as the base metal; to provide for other base metals such as brass (*B*) and zinc (*Z*).

NOTE 2: *Classification.*—The conditions of exposure and use of plated steel are so varied that it is not possible to predict the average life of articles plated in accordance with Type *LS* or Type *RS*, or to predetermine just which type of plating should be specified for a given article. Such a selection must be based upon the experience of the manufacturers and users.

It is recognized that uses exist for which thicker coatings than those of Type *LS* will be required.

For articles that are intended for a short period of use, no standard specification for plating is recommended. It is suggested, however, that subject to the prevailing manufacturing conditions, certain minimum requirements be mutually agreed upon by the manufacturer and purchaser in order to insure that the plated coatings render a useful service.

Manufacture

2. The steel to be plated shall be substantially free from flaws or defects that will be detrimental to the appearance or the protective value of the coatings. It shall be subjected to such cleaning, pickling and plating procedures as are necessary to yield deposits with the desired quality. The zinc coating shall have a uniform appearance, shall be adherent and free from blisters and substantially free from other defects that may affect the appearance or protective value of the coatings.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

These specifications were prepared under the joint cooperation of the American Electro-Platers' Society, the National Bureau of Standards and the American Society for Testing Materials.

Minimum Thickness of Deposits

3. (*a*) *Type LS.*—On significant surfaces of the finished articles, the minimum thickness of Type *LS* zinc coating shall be 0.0005 in.

(*b*) *Type RS.*—On significant surfaces of the finished articles, the minimum thickness of Type *RS* zinc coating shall be 0.00015 in.

Thickness Measurements

4. The minimum thickness of the zinc coatings shall be determined by microscopic examination of cross-sections taken perpendicular to significant surfaces, or by other methods as agreed upon by the manufacturer and purchaser.

Significant Surfaces

5. In general, significant surfaces are those surfaces that are visible and subjected to wear and/or corrosion. The designation of significant surfaces shall be agreed upon by the manufacturer and purchaser, and may be indicated on the drawings.

Sampling

6. Methods of sampling and resampling and the basis of rejection shall be subject to mutual agreement by the manufacturer and purchaser. The number of samples to be selected and the frequency of selection will, in general, depend upon the number of pieces to be plated.

APPENDIX

TIME REQUIRED FOR PLATING

Any specified thickness of plating can be produced consistently only if the current density and time of plating are controlled. Regulation of the voltage is of no value except so far as it produces the desired current density.

The average thickness of deposit that is required to produce a specified minimum thickness of deposit will depend upon the shape of the article, the shape and position of the anodes, and the throwing power of the solution. Purely for illustration, it will be assumed that the average thickness will be 50 per cent greater than the minimum thickness. The resultant figures serve only as a rough guide and must be confirmed by trial for the articles concerned.

To deposit 0.001 in. of zinc with high efficiency in either acid or cyanide baths, it requires about 14 amp. hr. per sq. ft. To produce an average thickness of 0.00075 in. (that is, 50 per cent more than the minimum thickness of 0.0005 in. specified for Type *LS*), it will therefore require about 11 amp. hr. per sq. ft. This is equivalent to one hour's plating at 11 amp. per sq. ft., or to a corresponding period for any other current density. Similarly, for Type *RS* it will require about 3.5 amp. hr. per sq. ft. to deposit an average of 0.00023 in. of zinc (or a minimum of 0.00015 in.).

For complicated shapes, longer periods will be required. When a large number of small articles are plated simultaneously (for example, on a rack or in a barrel), the time of plating must be increased to insure the specified thickness on those articles that receive less than the average current density.

TENTATIVE SPECIFICATIONS
FOR
ELECTRODEPOSITED COATINGS OF CADMIUM ON STEEL[1]

A.S.T.M. Designation: A 165 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover requirements for electroplated cadmium coatings on steel articles that are required to withstand corrosion. Two types of coating (Notes 1 and 2) are covered: namely,

Type NS.—For general service.

Type TS.—For mild service.

NOTE 1: *Explanation of Symbols.*—The initial letters *N* and *T* were adopted as arbitrary designations of grades of plating. The second letter (*S*) refers to steel as the base metal; to provide for other base metals such as brass (*B*) and zinc (*Z*).

NOTE 2: *Classification.*—The conditions of exposure and use of plated steel are so varied that it is not possible to predict the average life of articles plated in accordance with Type *NS* or Type *TS*, or to predetermine just which type of plating should be specified for a given article. Such a selection must be based upon the experience of the manufacturers and users.

It is recognized that uses exist for which thicker coatings than those of Type *NS* will be required.

For articles that are intended for a short period of use, no standard specification for plating is recommended. It is suggested, however, that subject to the prevailing manufacturing conditions, certain minimum requirements be mutually agreed upon by the manufacturer and purchaser in order to insure that the plated coatings render a useful service.

Manufacture

2. The steel to be plated shall be substantially free from flaws or defects that will be detrimental to the appearance or the protective value of the coatings. It shall be subjected to such cleaning, pickling and plating procedures as are necessary to yield deposits with the desired quality. The cadmium coating shall have a uniform appearance, bright or dull as specified, shall be adherent and free from blisters and substantially free from other defects that may affect the appearance or protective value of the coatings.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

These specifications were prepared under the joint cooperation of the American Electro-Platers' Society, the National Bureau of Standards and the American Society for Testing Materials.

Minimum Thickness of Deposits

3. (*a*) *Type NS.*—On significant surfaces of the finished articles, the minimum thickness of Type *NS* cadmium coating shall be 0.0005 in.

(*b*) *Type TS.*—On significant surfaces of the finished articles, the minimum thickness of Type *TS* cadmium coating shall be 0.00015 in.

Thickness Measurements

4. The minimum thickness of the cadmium coating shall be determined by microscopic examination of cross-sections taken perpendicular to significant surfaces, or by other methods as agreed upon by the manufacturer and purchaser.

Significant Surfaces

5. In general, significant surfaces are those surfaces that are visible and subjected to wear and/or corrosion. The designation of significant surfaces shall be agreed upon by the manufacturer and purchaser, and may be indicated on the drawings.

Sampling

6. Methods of sampling and resampling and the basis of rejection shall be subject to mutual agreement by the manufacturer and purchaser. The number of samples to be selected and the frequency of selection will, in general, depend upon the number of pieces to be plated.

APPENDIX

TIME REQUIRED FOR PLATING

Any specified thickness of plating can be produced consistently only if the current density and time of plating are controlled. Regulation of the voltage is of no value except so far as it produces the desired current density.

The average thickness of deposit that is required to produce a specified minimum thickness of deposit will depend upon the shape of the article, the shape and position of the anodes, and the throwing power of the solution. Purely for illustration, it will be assumed that the average thickness will be 50 per cent greater than the minimum thickness. The resultant figures serve only as a rough guide and must be confirmed by trial for the articles concerned.

To deposit 0.001 in. of cadmium with high efficiency, it requires about 10 amp. hr. per sq. ft. To produce an average thickness of 0.00075 in. (that is, 50 per cent more than the minimum thickness of 0.0005 in. specified for Type *NS*), it will therefore require about 7.5 amp. hr. (450 amp. min.) per sq. ft. This is equivalent to one hour's plating at 7.5 amp. per sq. ft., or to a corresponding period for any other current density. Similarly, for Type *TS* it will require about 2.5 amp. hr. per sq. ft. to deposit an average of 0.00023 in. of cadmium (or a minimum of 0.00015 in.).

For complicated shapes, longer periods will be required. When a large number of small articles are plated simultaneously (for example, on a rack or in a barrel), the time of plating must be increased to insure the specified thickness on those articles that receive less than the average current density.

TENTATIVE SPECIFICATIONS

FOR

ELECTRODEPOSITED COATINGS OF NICKEL AND CHROMIUM ON STEEL[1]

A.S.T.M. Designation: A 166 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover requirements for electroplated coatings on steel articles including a final coating of nickel or chromium where both appearance and protection against corrosion of the base metal are important. Two types of coating (Notes 1 and 2) are covered: namely,

Type KS.—For general service.

Type QS.—For mild service.

NOTE 1: *Explanation of symbols.*—The initial letters *K* and *Q* were adopted as arbitrary designations of grades of plating. The second letter (*S*) refers to steel as the base metal; to provide for other base metals such as brass (*B*) and zinc (*Z*).

NOTE 2: *Classification.*—The conditions of exposure and use of plated steel are so varied that it is not possible to predict the average life of articles plated in accordance with Type *KS* or Type *QS*, or to predetermine just which type of plating should be specified for a given article. Such a selection must be based upon the experience of the manufacturers and users.

It is recognized that uses exist for which thicker coatings than those of Type *KS* will be required.

For articles that are intended for a short period of use, no standard specification for plating is recommended. It is suggested, however, that subject to the prevailing manufacturing conditions, certain minimum requirements be mutually agreed upon by the manufacturer and purchaser in order to insure that the plated coatings render a useful service.

Manufacture

2. The steel to be plated shall be substantially free from flaws or defects that will be detrimental to the final finish. It shall be subjected to such polishing, cleaning, pickling and plating procedures as are necessary to yield deposits with the desired appearance and quality. The use of copper as an initial or intermediate layer is optional, and subject to the requirements specified in Sections 3 and 4. The coatings shall have a

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-5 on Corrosion of Iron and Steel.

These specifications were prepared under the joint cooperation of the American Electro-Platers' Society, the National Bureau of Standards and the American Society for Testing Materials.

bright or dull finish as specified, shall be adherent and free from blisters, and substantially free from pits or other surface defects.

Thickness of Deposits, Type KS

3. (*a*) *Nickel and Copper.*—For Type *KS* coating on significant surfaces of the finished articles, the minimum thickness of the nickel coating, or of the combined layers of copper and nickel, shall be 0.00075 in., and if copper is used, the minimum thickness of the final nickel layer shall be 0.0004 in.

(*b*) *Chromium.*—If a chromium finish is specified, the minimum thickness of the copper and nickel layers on significant surfaces shall be as specified in Paragraph (*a*), and the average[1] thickness of the chromium coating shall be not less than 0.00002 in.

Thickness of Deposits, Type QS

4. (*a*) *Nickel and Copper.*—For Type *QS* coating on significant surfaces of the finished articles, the minimum thickness of the nickel coating, or of the combined layers of copper and nickel, shall be 0.0004 in., and if copper is used, the minimum thickness of the final nickel layer shall be 0.0002 in.

(*b*) *Chromium.*—If a chromium finish is specified, the minimum thickness of the copper and nickel layers on significant surfaces shall be as specified in Paragraph (*a*), and the average[1] thickness of the chromium coating shall be not less than 0.00002 in.

Thickness Measurements

5. (*a*) The minimum thicknesses of the copper and nickel coatings shall be determined by microscopic examination of cross-sections taken perpendicular to significant surfaces.

(*b*) The average thickness of the chromium coating shall be determined by microscopic examination of cross-sections taken perpendicular to significant surfaces, by stripping methods, or by other methods as agreed upon by the manufacturer and purchaser.

Continuity Tests

6. (*a*) For Type *KS* coating the plated articles shall show no appreciable corrosion on significant surfaces at the end of 48-hr. continuous exposure to the salt spray test; and for Type *QS* coating at the end of 16-hr. continuous exposure to the salt spray test (Note 3).

NOTE 3: *Preparation of Specimen.*—The specimen shall be cleaned immediately before insertion in the salt spray, so that the surface is free from "water break." This may be accomplished by any efficient method, such as cleaning with a suitable organic solvent followed by light rubbing with a cream of pure magnesium oxide.

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[1] For many articles the minimum thickness of chromium is more significant, but the average thickness has been specified pending the development of satisfactory methods for measuring the minimum thickness.

Salt Spray Test.—The test shall be conducted with a 20 per cent solution of sodium chloride (sp. gr. 1.15) under conditions that produce a dense fog throughout the container, without the spray being blown directly against the specimens. The latter shall be supported by glass or other insulating material. The temperature in the box shall be maintained by thermostatic control at 95 F. ± 5 F. (35 C ± 3 C.). (This is about the lowest temperature that can be maintained throughout the year without artificial cooling.) The solution formed by condensation of the spray should be drained off and not used again.

(*b*) Unless otherwise agreed upon by the manufacturer and purchaser, "appreciable corrosion" shall be defined as the presence of more than six rust spots per square foot that are visible to the unaided eye, or of any rust spots larger than $\frac{1}{16}$ in. in diameter.

NOTE 4: *Summary.*—The requirements of Sections 3, 4, and 6 are summarized as follows:

	TYPE *KS* COATING	TYPE *QS* COATING
Minimum Thickness:		
Copper plus Nickel	0.00075 in.	0.0004 in.
Final Nickel	0.0004 in.	0.0002 in.
Average Thickness:		
Chromium (if required)	0.00002 in.	0.00002 in.
Salt spray, continuous exposure	48 hr.	16 hr.

Significant Surfaces

7. In general, significant surfaces are those surfaces that are visible and subjected to wear and/or corrosion. The designation of significant surfaces shall be agreed upon by the manufacturer and purchaser, and may be indicated on the drawings.

Sampling

8. Methods of sampling and resampling and the basis of rejection shall be subject to mutual agreement by the manufacturer and purchaser. The number of samples to be selected and the frequency of selection will, in general, depend upon the number of pieces to be plated.

APPENDIX

TIME REQUIRED FOR PLATING

Any specified average or minimum thickness of plating can be produced consistently only if the current density and time of plating are controlled. Regulation of the voltage is of no value except so far as it produces the desired current density.

The current and time required to produce a certain minimum thickness of any metal will depend upon the shape of the article, the shape and position of the anodes, and the throwing power of the solution. General experience indicates that average thicknesses of at least 0.001 in. and 0.0005 in. will usually be required to produce the respective minimum thicknesses of 0.00075 in. and 0.0004 in. of nickel plus copper. For complicated shapes, longer periods will be required, which must be determined by trial. When a large number of small articles are plated simultaneously (for example, on racks or in barrels), the time of plating must be increased to insure the specified thickness on those articles that receive less than the average current density.

Copper and Nickel.—To deposit an average thickness of 0.001 in. of either copper or nickel using acid baths with 90 per cent efficiency, requires about 21 amp. hr. per sq. ft. In the cyanide copper bath only about 10 amp. hr. per sq. ft. are required if the efficiency is over 90 per cent. Practically, however, the efficiency in cyanide baths may be only 50 to 70 per cent, so for illustration the above figure of 21 amp. hr. per sq. ft. will be retained for all the copper layers.

The losses in buffing may vary from 10 to 20 per cent. If the latter value is assumed for safety, this will necessitate the use of 21 + 4 = 25 amp. hr. (1500 amp. min.) per sq. ft. to yield an average thickness of 0.001 in. of copper plus nickel on the finished articles. This is equivalent to a total of one hour's plating at 25 amp. per sq. ft., 2.5 hr. at 10 amp. per sq. ft., or to a corresponding period for any other current density. For an average thickness of 0.0005 in., half these periods will be required.

Chromium.—In chromium plating, bright deposits are usually produced with a cathode efficiency of about 12 per cent. Under these conditions it requires about 500 amp. min. per sq. ft. to produce the specified average thickness of 0.00002 in. of chromium. This is equivalent to 5 minutes' plating at 100 amp. per sq. ft., or to 2.5 min. at 200 amp. per sq. ft.

TENTATIVE SPECIFICATIONS
FOR
WROUGHT-IRON PLATES[1]

A.S.T.M. Designation: A 42 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.

Scope

1. These specifications cover wrought-iron[2] plates for general fabrication purposes, including bending and flanging, in thicknesses $\frac{3}{16}$ in. and over.

Manufacture

2. (*a*) All plates shall be rolled from blooms, piles or slabs which are entirely free from any admixture of iron scrap (Note) or steel.

(*b*) Piles for plates shall be made from wrought iron.[2] The constituent bars shall be the full length of the pile.

NOTE.—The term iron scrap applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal or of a higher grade than the material specified.

Chemical Composition

3. The iron shall conform to the following requirement as to chemical composition:

Manganese, max., per cent.................................... 0.05

Tension Tests

4. (*a*) The plates shall conform to minimum requirements as to tensile properties, calculated from the following formulas:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

These tentative specifications are in effect a tentative revision of, and will supersede when adopted as standard, the present Standard Specifications for Wrought-Iron Plates (A.S.T.M. Designation: A 42 - 30), 1933 Book of A.S.T.M. Standards, Part I, p. 459.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Tensile strength, lb. per sq. in. = 51,000 − (1500 × transverse ductility of plate (expressed as percentage elongation in 8 in.))

Longitudinal elongation in 8 in., per cent = 16 − transverse ductility (expressed as percentage elongation in 8 in.)

Yield point, lb. per sq. in 27,000

(*b*) On the basis of the above formulas, the purchaser of the plate shall indicate the transverse ductility desired in conformity with his fabrication requirements. The usual longitudinal strength and ductility are directly related thereto, and are scaled downward in ratio to the increase in transverse properties desired.

(*c*) Representative requirements in accordance with the formulas are as follows:

	Minimum Longitudinal Properties	
Transverse Ductility (Elongation in 8 in.), per cent	Tensile Strength,[a] min., lb. per sq. in.	Elongation[b] in 8 in., min., per cent
2	51,000 − (1500 × 2) = 48 000[c]	(16 − 2) = 14[c]
3	46 500	13
4	45 000	12
5	43 500	11
6	42 000	10
7	40 500	9
8	39 000	8

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[a] See Section 5 (*a*).
[b] See Section 5 (*b*).
[c] Test requirements for the usual full longitudinal rolling of the plate.

(*d*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine. The speed of the crosshead of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Elongation

5. (*a*) For plates over $\frac{3}{4}$ in. in thickness, a reduction of 1000 lb. per sq. in. from the indicated tensile strength will be allowed for each increase of $\frac{1}{8}$ in. in thickness over $\frac{3}{4}$ in., with a proportional reduction for fractional parts of $\frac{1}{8}$ in.; but in no case less than 39,000 lb. per sq. in.

(*b*) For plates under $\frac{7}{16}$ in. in thickness, a deduction of 1 per cent from the percentages of elongation specified in Section 4 shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{7}{16}$ in.

Bend Tests

6. (*a*) *Cold-bend Tests.*—The test specimen shall stand being bent cold through 90 deg., without fracture on the outside of the bent portion, around a pin the diameter of which is:

$$d = \frac{40 \times \text{thickness of plate}}{\text{specified longitudinal elongation in 8 in., per cent}}$$

(*b*) *Nick-bend Tests.*—The test specimen, when nicked on one side and slowly broken, shall show a wholly fibrous fracture.

Test Specimens

7. (*a*) Tension and bend test specimens shall be taken from the finished plate and except as specified in Paragraph (*b*) shall be of the full thickness of the plate as rolled.

(*b*) Test specimens may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel. When plates are $1\frac{1}{2}$ in. or over in thickness, the specimens may be machined to a thickness of not less than $\frac{3}{4}$ in. or, if desired, to a diameter of not less than $\frac{3}{4}$ in. for a distance of not less than 9 in.

(*c*) The machined edges of rectangular bend test specimens may be rounded to a radius of not over $\frac{1}{16}$ in.

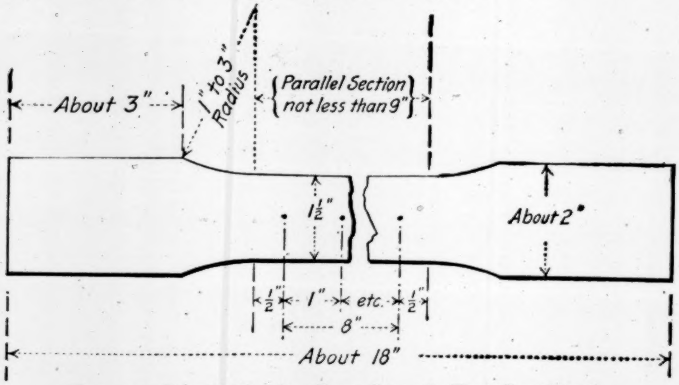

FIG. 1.—Standard 8-in. Gage Length Test Specimen.

Number of Tests

8. (*a*) One tension, one cold-bend and one nick-bend test shall be made for each $\frac{1}{8}$-in. variation in plate thickness and not less than one test for every ten plates as rolled. Where modification of the usual transverse properties is specified, and the tensile properties are determined by the formulas in Section 4 (*a*), two tension test specimens shall be taken at right angles to each other, one parallel to the longitudinal axis and the other parallel to the transverse axis.

(*b*) If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen fails to meet the physical requirements of Section 4 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different plate will be allowed. If the retest also fails, the plates represented by such test will be rejected.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

Ordered Weight, lb. per sq. ft.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																		Ordered Weight, lb. per sq. ft.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over		
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than one and one-third the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$	9	10	12	14	....	....	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	....	....	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ " $\frac{1}{4}$ "	7	8	9	10	12	....	..	..	..	$\frac{3}{16}$ " $\frac{1}{4}$ "
$\frac{1}{4}$ " $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ " $\frac{5}{16}$ "
$\frac{5}{16}$ " $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ " $\frac{3}{8}$ "
$\frac{3}{8}$ " $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ " $\frac{7}{16}$ "
$\frac{7}{16}$ " $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ " $\frac{1}{2}$ "
$\frac{1}{2}$ " $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ " $\frac{5}{8}$ "
$\frac{5}{8}$ " $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ " $\frac{3}{4}$ "
$\frac{3}{4}$ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

Other Tests

9. Where desired, the purchaser may, at his own expense, subject the material to chemical, microscopic, or other tests to determine its quality in conformity with the intent of these specifications.

Variations in Weight and Thickness

10. The weight or thickness of plates shall be covered by the following permissible variations. One cubic inch of wrought iron is assumed to weigh 0.2776 lb.

(*a*) *Plates, When Ordered to Weight per Square Foot.*—The weight of each lot[1] of plates in each shipment shall not vary from the weight ordered more than the amounts given in Table I.

(*b*) *Plates, When Ordered to Thickness.*—The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight in each lot[1] of plates in each shipment shall not exceed the amounts given in Table II.

Finish

11. The plates shall be straight, smooth and free from cinder spots and holes, injurious flaws, buckles, blisters, seams and laminations.

Marking

12. The plates shall be stamped or otherwise marked as designated by the purchaser.

Inspection

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the plates ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of plates at his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

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[1] The term "lot" as applied to Table I means all the plates of each group width and group weight. As applied to Table II, it means all the plates of each group width and group thickness.

Rejection

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

15. Samples tested in accordance with Section 13 (*b*), which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

WROUGHT-IRON RIVETS AND RIVET ROUNDS[1]

A.S.T.M. Designation: A 152 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1935.

A. Requirements for Rolled Bars

MANUFACTURE

Process

1. The rivet bars shall be made from wrought iron[2] which shall be free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal or of a higher grade than the material specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

2. The wrought iron shall conform to the following requirement as to chemical composition:

Manganese, max., per cent.................................. 0.05

Check Analyses

3. (*a*) Analyses may be made by the purchaser from a broken test specimen representing each lot, as specified in Section 7 (*a*). At the discretion of the purchaser, the chemical analysis may be made from a rivet. Each rivet so tested shall not represent more than 2000 lb. of any one size.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

PHYSICAL PROPERTIES AND TESTS

Tension Tests

4. (*a*) The wrought iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.		47 000
Yield point, lb. per sq. in.		0.6 tens. str.
Elongation[a] in 8 in., per cent	rounds ½ to ¾ in., incl., in diam.	24
	rounds over ¾ to 2 in., incl., in diam.	28

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[a] See Paragraph (*b*).

(*b*) Rounds under ½ in. in diameter will not be required to meet an elongation requirement.

(*c*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine.

Bend Tests

5. (*a*) *Quenched, Cold-bend Tests.*—A test specimen shall be heated between 1600 and 1700 F. (870 and 925 C.), and quenched in cold water, after which it shall stand being bent cold through 90 deg. on a radius which is equal to the diameter of the specimen without fracture on the outside of the bent portion.

(*b*) *Nick-bend Tests.*—A test specimen, when nicked 25 per cent around the circumference with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken slowly, shall show a wholly fibrous fracture.

(*c*) *Hot-bend Tests.*—A test specimen, when heated to a temperature between 1700 and 1800 F. (925 and 980 C.), shall stand being bent through 180 deg. flat on itself without fracture on the outside of the bent portion.

(*d*) Bend tests may be made by pressure or blows.

Test Specimens

6. All test specimens shall be of the full section of the material as rolled.

Number of Tests

7. (*a*) All bars of a given size shall be piled separately, sorted in lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified in Sections 4 to 6.

(*b*) If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen fails to meet the physical test requirements of Section 4 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different bar will be allowed.

Micrographic Examination

8. In case of doubt as to the presence of steel, the purchaser may, at his own expense, make micrographic examination to assist in determining whether the material conforms to the requirements of Section 1.

Permissible Variations

9. The diameter of rivet bars shall not vary from that specified by more than the amount given in the following table:

DIAMETER, IN.	PERMISSIBLE VARIATIONS IN DIAMETER, IN.	OUT OF ROUND, IN.
Up to ½, inclusive	±0.007	0.010
Over ½ to 1, inclusive	±0.010	0.013
Over 1 to 1¼, inclusive	±0.012	0.016
Over 1¼ to 1½, inclusive	±0.015	0.021
Over 1½ to 2, inclusive	±0.022	0.023

Finish

10. The bars shall be smoothly rolled and shall be free from slivers, depressions, crop ends and seams, and shall show no evidence of being burnt.

INSPECTION AND REJECTION

Inspection

11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

12. (*a*) All bars of one size in any one lot will be rejected if the test specimens representing that size and lot do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 11 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing

13. Samples tested in accordance with Section 11 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Finished Rivets

Material

14. The material used in the manufacture of the rivets shall conform to the requirements for rolled bars as specified in Sections 1 to 13, inclusive.

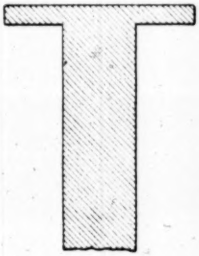

FIG. 1.—Flattening Test.

PHYSICAL PROPERTIES AND TESTS

Flattening Test

15. The rivet head shall stand being flattened, while hot, to a diameter two times the diameter of the shank, as shown in Fig. 1, without cracking at the edges.

Etch Test

16. The rivet shall be split longitudinally through head and shank. After grinding or polishing and etching in acid,[1] the section shall show freedom of folds at base of head, and the fiber lines shall show symmetrical displacement. (See Fig. 2).

Number of Tests

17. Three flattening and three etch tests shall be made from

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[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp gr. 1.42) and 75 per cent water, is recommended for the etch test.

each lot of 2000 lb. or less of any one diameter of rivets offered for inspection, each of which shall conform to the requirements specified in Sections 15 and 16.

WORKMANSHIP AND FINISH

Workmanship and Finish

18. The rivets shall be true to form and concentric, shall be made in a workmanlike manner, and shall be free from injurious defects. The heads shall not show cracks or splits on the edge but may contain a slight flash.

INSPECTION AND REJECTION

Inspection

19. The inspector representing the purchaser shall have free entry, at all times while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture of the rivets prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

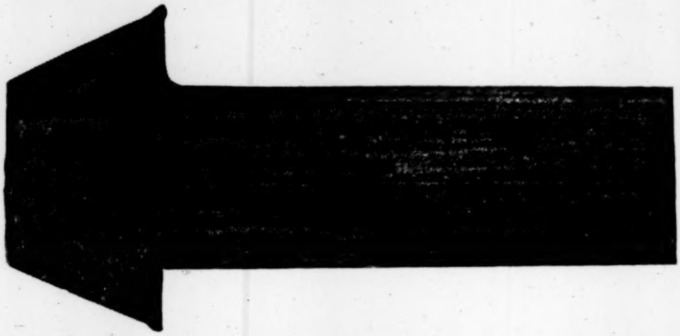

FIG. 2.—Showing Symmetrical Displacement of Fiber Lines After Etching Test.

Rejection

20. Rivets which show defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS

FOR

UNCOATED WROUGHT-IRON SHEETS[1]

A.S.T.M. Designation: A 162 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover wrought-iron[2] sheets for use in roofing, siding, for corrugating and other moderate forming requirements. It is not advisable to use such sheets where excessive forming, such as severe sharp right-angled bends, is required, or drawing operations where the material is severely stretched.

Process

2. All sheets shall be rolled from slabs, piles, or bars made from wrought iron,[2] and shall be free from any admixture of iron scrap (Note) or steel.

NOTE.—The term iron scrap applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal of or of a higher grade than the material specified.

Chemical Composition

3. The sheet shall conform to the following requirement as to chemical composition:

Manganese, max., per cent	0.05

Bend Tests

4. (*a*) Any part of the bend test specimen shall stand being bent cold without fracture as follows: Where the line (axis) of the bend is parallel to the length of the sheet, 180 deg. over seven thicknesses of the material; and where the line (axis) of the bend is parallel to the width of the sheet, 180 deg. over three thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend test.

(*b*) The bend test specimens shall be from 3 to 4 in. in width and shall be cut from the test sheet at least 4 in. from the end and 2 in. from the side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pastry particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

(*c*) The bend test shall be made on a specimen from one sheet in each lot of 250 sheets or fraction thereof of each gage.

(*d*) If any test fails to meet the requirements, a retest shall be made from two other sheets of the same lot, both of which shall meet the requirements.

Weight

5. (*a*) The weight per square foot shall conform to the following requirements:

GAGE	WEIGHT PER SQUARE FOOT, LB.	APPROXIMATE THICKNESS, FRACTIONS OF AN INCH	APPROXIMATE THICKNESS, DECIMALS OF AN INCH
No. 8	6.875	$\frac{11}{64}$	0.172
No. 9	6.25	$\frac{5}{32}$	0.156
No. 10	5.625	$\frac{9}{64}$	0.141
No. 11	5.00	$\frac{1}{8}$	0.125
No. 12	4.375	$\frac{7}{64}$	0.109
No. 13	3.75	$\frac{3}{32}$	0.094
No. 14	3.125	$\frac{5}{64}$	0.078
No. 15	2.8125	$\frac{9}{128}$	0.070
No. 16	2.50	$\frac{1}{16}$	0.063
No. 17	2.25	$\frac{9}{160}$	0.056
No. 18	2.00	$\frac{1}{20}$	0.050
No. 19	1.75	$\frac{7}{160}$	0.044
No. 20	1.50	$\frac{3}{80}$	0.038
No. 21	1.375	$\frac{11}{320}$	0.034
No. 22	1.25	$\frac{1}{32}$	0.031
No. 23	1.125	$\frac{9}{320}$	0.028
No. 24	1.00	$\frac{1}{40}$	0.025
No. 25	0.875	$\frac{7}{320}$	0.022
No. 26	0.75	$\frac{3}{160}$	0.019
No. 27	0.6875	$\frac{11}{640}$	0.017
No. 28	0.625	$\frac{1}{64}$	0.016

(*b*) A permissible variation in tonnage weight of $2\frac{1}{2}$ per cent over or under for gages Nos. 17 to 28, inclusive, and 5 per cent over or under for gages No. 16 and heavier shall be allowed.

Dimensions

6. Sheets shall conform to the dimensions specified, within the permissible variations prescribed in the following Paragraphs (*a*) to (*c*):

(*a*) The width shall not be less than specified, but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall not be less than that specified, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof over 96 in., the permissible variation may be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "re-squared." Re-squared sheets shall not be less than the ordered width and length and shall not be more than $\frac{1}{16}$ in. over the ordered width and length, except for sheets over 48 in. in width or over 120 in. in length, in which case the permissible variation over the ordered size shall be $\frac{1}{8}$ in.

Marking

7. The top sheet of each bundle or the top sheet of a number of sheets when shipped loose, shall show legibly the name and brand of the manufacturer, gage and size, unless otherwise ordered.

Inspection

8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer of the material ordered shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

9. (*a*) Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected, and the manufacturer shall be notified.

(*b*) Samples tested in accordance with these specifications which represent rejected material shall be preserved for two weeks from the date of the test report.

TENTATIVE SPECIFICATIONS
FOR
ZINC-COATED (GALVANIZED) WROUGHT-IRON SHEETS[1]

A.S.T.M. Designation: A 163 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover wrought-iron[2] sheets for use in culverts, roofing, siding, for corrugating and moderate forming, with four classes of zinc coatings applied by the hot-dip process as follows:

Classes A and B.—Extra-heavy and heavy coated sheets that are not intended to be formed other than by corrugating and curving to large radii.

Class C.—Moderately heavily coated sheets for moderate bending.

Class D.—Ordinary sheets for general utility. These coatings approximate those of Class *C* except in the medium and light gages, in which class the coating may be appreciably lighter. No definite weight of coating is guaranteed and sheets are not subject to coating tests.

Process

2. All sheets shall be rolled from slabs, piles or bars made from wrought iron,[2] and shall be free from any admixture of iron scrap (Note) or steel.

NOTE.—The term iron scrap applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal of or of a higher grade than the material specified.

Chemical Composition

3. The base metal of the sheets shall conform to the following requirement as to chemical composition:

Manganese, max., per cent..0.05

Weight of Coating

4. The weight of the zinc coating shall conform to the requirements specified in Tables I and II. Different methods of sampling and testing give different results as indicated in Table II. The purchaser shall specify which method shall be used. The weight of coating is the total coating, expressed in ounces, on both sides of a sheet 1 ft. square.

Weight of Coating Tests

5. (*a*) *Weight Test.*—The weight test is to be preferred and shall consist of a 10-sheet lot of a light gage, or a 5-sheet lot of No. 16 gage or

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

heavier. The weight test shall be performed in accordance with the shop weighing method as described in Sections 2 to 4 of the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A.S.T.M. Designation: A 90) of the American Society for Testing Materials.[1] The average of the weight tests shall be determined from not less than ten successive weight tests that have met the requirements of these specifications as provided in Section 8 (*a*).

TABLE I.—DESIRED OR ORDERED WEIGHT OF COATINGS IN OUNCES PER SQUARE FOOT.

GALVANIZED SHEET GAGE	CLASS A	CLASS B	CLASS C	CLASS D
No. 8	2.75	2.50	2.00	No specified coatings (See Section 1)
No. 9	2.75	2.50	2.00	
No. 10	2.75	2.50	2.00	
No. 11	2.75	2.50	2.00	
No. 12	2.75	2.50	2.00	
No. 13	2.75	2.50	2.00	
No. 14	2.75	2.50	2.00	
No. 16	2.75	2.50	2.00	
No. 18	2.75	2.50	1.75	
No. 20	2.75	2.50	1.75	
No. 22	2.75	2.50	1.75	
No. 24	....	2.50	1.50	
No. 26	....	2.25	1.25	
No. 28	....	1.75	1.25	

TABLE II.—MINIMUM WEIGHT OF COATING LIMITS IN OUNCES PER SQUARE FOOT.

Class According to Desired or Ordered Coating	Average of Weight Tests	Any One Weight Test	Average of Triple Spot Tests	Any One Triple Spot Test	Average of Minimum Spot Tests	Any One Minimum Spot Test
2.75	2.60	2.45	2.40	2.30	2.20	2.00
2.50	2.30	2.20	2.15	2.00	1.95	1.80
2.25	2.10	2.00	1.95	1.80	1.75	1.60
2.00	1.90	1.80	1.75	1.60	1.55	1.40
1.75	1.65	1.55	1.50	1.35	1.30	1.20
1.50	1.40	1.30	1.25	1.15	1.10	1.00
1.25	1.15	1.10	1.05	0.95	0.90	0.85

(*b*) *Triple Spot Test.*—The triple spot test shall consist of the average of determinations from the three specimens cut from the test sheet as provided in Sections 7 and 8 (*b*). The average of triple spot tests shall be determined from not less than ten successive triple spot tests and shall include all such tests made.

(*c*) *Minimum Spot Test.*—The minimum spot test shall be that one of the three specimens of the triple spot test bearing the lightest coating, or the purchaser may select a single specimen taken from any part of the sheet, at least 2 in. from the side and 4 in. from the end. The average of the minimum spot tests shall be determined from not less than ten successive minimum spot tests and shall include all such tests made.

(*d*) The weight of the zinc coating by triple and minimum spot tests shall be determined by the hydrochloric acid - antimony chloride, or sulfuric-acid method, as described in Sections 5 to 9 of the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A.S.T.M. Designation: A 90) of the American Society for Testing Materials.[1] The weight of coating, in ounces per square foot, is numerically equal to that determined in grams from a sample 2¼ in. square.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 317.

Bend Tests

6. (*a*) *Base Metal Tests.*—Any part of the test specimen specified in Section 7 shall stand being bent cold without fracture of the base metal as follows: Where the line (axis) of the bend is parallel to the length of the sheet, 180 deg. over seven thicknesses of the material; and where the line (axis) of the bend is parallel to the width of the sheet, 180 deg. over three thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend tests.

(*b*) *Coating Tests.*—Sheets of Classes *A* and *B* of the following gages shall stand corrugating and also subsequent curving, as given below, without flaking of the coating. The corrugation for these tests shall not be less than 2⅔ in. in width and not more than ½ in. in depth.

GAGE	DIAMETER OF CIRCLE
No. 12	30 in.
No. 14	18 in.
No. 16	12 in.

For sheets of Class *C* of No. 16 gage and lighter, any part of the test specimen specified in Section 7 shall stand being bent with the line (axis) of the bend parallel to the width of the sheet through 180 deg. over three thicknesses of the material without flaking of the coating.

Test Specimens

7. For the triple and minimum spot tests, three specimens exactly 2¼ in. square shall be cut from each test sheet, one being cut from the center and the others from diagonally opposite corners, but at least 4 in. from the end and 2 in. from the side. The bend test specimens shall be from 3 to 4 in. in width and shall be cut from the test sheet at least 4 in. from the end and 2 in. from the side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

Number of Tests

8. (*a*) Weight tests shall be made of not less than 1 per cent of the sheets of each gage and ordered coating, or at approximately hourly periods. If an inspector representing the purchaser witnesses and accepts weight

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 317.

tests, the triple and minimum spot tests shall not be made. If a certificate of weight tests be accepted, the triple and minimum spot tests shall not be made.

(*b*) The bend and spot tests, if required, shall be made from one sheet in each lot of 250 sheets or fraction thereof, of each gage and ordered coating.

(*c*) If any test fails to meet the requirements of these specifications, a retest shall be made from two other sheets in the same lot, both of which shall meet the requirements.

Dimensions and Permissible Variations

9. The sheets shall conform to the dimensions specified within the permissible variations prescribed in the following Paragraphs (*a*) to (*c*):

(*a*) The width shall not be less than that specified but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall not be less than that ordered, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof above 96 in., the permissible variation shall be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "re-squared." Re-squared sheets shall not be less than the ordered width and length and shall not be more than $\frac{1}{16}$ in. over the ordered width and length, except in the case of sheets over 48 in. in width or over 120 in. in length, in which case the permissible variation from the ordered size shall be $\frac{1}{8}$ in. Should the sheets be re-squared before galvanizing, double the foregoing tolerances are permissible.

Weight

10. The gage of galvanized sheets shall be determined by weight only. The weight per square foot of galvanized sheet shall conform to the following requirements within the permissible variations prescribed in Table III:

Galvanized Sheet Gage	Weight of Galvanized Sheets, All Classes, oz. per sq. ft.	Weight of Galvanized Sheets, All Classes, lb. per sq. ft.
No. 8	112.5	7.031
No. 9	102.5	6.406
No. 10	92.5	5.781
No. 11	82.5	5.156
No. 12	72.5	4.531
No. 13	62.5	3.906
No. 14	52.5	3.281
No. 16	42.5	2.656
No. 18	34.5	2.156
No. 20	26.5	1.656
No. 22	22.5	1.406
No. 24	18.5	1.156
No. 26	14.5	0.906
No. 27	13.5	0.844
No. 28	12.5	0.781
No. 29	11.5	0.719
No. 30	10.5	0.656

Finish

11. The finished sheet shall be of first-class commercial quality, free from injurious defects, flux and uncoated spots.

Marking

12. The top sheet of each bundle, or the top sheet of a number of sheets when shipped loose, shall show legibly the name and brand of the manufacturer, class, gage and size, unless otherwise ordered.

Inspection

13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except triple and minimum spot tests) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE III.—PERMISSIBLE VARIATIONS IN WEIGHTS OF SHEETS, PLUS OR MINUS, IN PERCENTAGE OF THEORETICAL WEIGHT[a]

GALVANIZED SHEET GAGE NUMBER		ALL OF ONE GAGE AND SIZE IN SHIPMENT[b]	SINGLE PACKAGES	SINGLE SHEETS
LIGHTER THAN	NOT LIGHTER THAN			
......	No. 16	5.0	7.0	10.0
No. 16	No. 22	3.5	5.5	10.0
No. 22	No. 28	2.5	4.0	10.0

---

[a] References are to gross weight of bundled material and to net weight of crated and boxed material. If sheets be ordered to minimum or maximum tolerances only, double the tolerance specified in the above table shall be allowed on the permissible side.

[b] All of one gage and size on shipment shall apply to lots of not less than 6000 lb.

Rejection

14. Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected and the manufacturer shall be notified.

Rehearing

15. Samples tested in accordance with Section 8 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report.

TENTATIVE SPECIFICATIONS
FOR
AUTOMOTIVE GRAY-IRON CASTINGS[1]

A.S.T.M. Designation: A 159 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

These Specifications are Identical in Substance with the S.A.E. Standard for Automotive Gray-Iron Castings.

Scope

1. These specifications cover gray-iron castings used in the automotive and allied industries.

Melting Practice

2. If desired, melting procedure may be specified by agreement between the manufacturer and purchaser.

PHYSICAL PROPERTIES AND TESTS

Hardness

3. The hardness of castings shall conform to the requirements shown in Table I for plain cast iron and in Table II for alloy cast iron.

Hardness Tests

4. Hardness tests shall be made on the castings on those portions specified. If desired, by agreement between the manufacturer and purchaser, hardness tests on test bars may be specified as a means of correlation with the hardness of castings.

Transverse Strength

5. The transverse test bar when placed horizontally upon supports and tested under a centrally applied load shall conform to the requirements shown in Table I for plain cast iron and in Table II for alloy cast iron. The values shown in Tables I and II are for the 1.2-in. diameter bar.

Transverse Tests

6. Transverse tests shall be made on arbitration bars as described in the Tentative Specifications for Gray-Iron Castings (A.S.T.M. Designation: A 48 – 35 T) of the American Society for Testing Materials.[2] In

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

[2] See p. 713.

case the size of the transverse test bars is not specified, the 1.2-in. diameter bar shall be used.

Tensile Strength

7. Tension tests are not recommended as a part of these specifications except upon mutual agreement between the manufacturer and purchaser. In general, tension tests are for information only. Where tension tests are made, the tension test specimens shall be machined from that portion of the casting where specified. The dimensions of the tension test specimen will be governed by the section of the casting from which it is machined. The tensile strengths shown in Table I for plain cast iron and in Table II for alloy cast iron refer to test specimens machined from castings. If desired, by mutual agreement between the manufacturer and purchaser, tension test specimens may be machined from arbitration test bars and tested in accordance with the Tentative Specifications for Gray-Iron Castings (A.S.T.M. Designation: A 48 – 35 T) of the American Society for Testing Materials.[1]

TABLE I.—PHYSICAL PROPERTIES[a] OF PLAIN CAST IRON.

No.[b]	Hardness[c]	Transverse Strength, min., lb.	Transverse Deflection, min., in.	Tensile Strength, min., lb. per sq. in.	Uses
110	¼-in. sections: Brinell, 192 max. Sections over ¼ in: Brinell, 163 max.	....	....	......	Miscellaneous soft iron castings
111	Brinell, 163 to 207	1800	0.20	30 000	Cylinders, flywheels, transmission cases
112	Rockwell "B," 98 to 106	....	....	....	Piston rings

[a] For more complete information on physical properties, etc., see A.F.A.-A.S.T.M. Symposium on Cast Iron, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 115 (1933).

[b] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

[c] Brinell hardness tests are to be made using 10-mm. ball and 3000-kg. load.

TABLE II.—PHYSICAL PROPERTIES[a] OF ALLOY CAST IRON.

No.[b]	Hardness[c]	Transverse Strength, min., lb.	Transverse Deflection, lb.	Tensile Strength, min., lb. per sq. in.	Uses
120	Brinell, 207 to 241	2200	0.20 min.	35 000	Cylinders
121	Brinell, 179 to 212	2700	0.27 to 0.37	40 000	Cylinders
122	Brinell, 217 to 248	3300	0.30 to 0.36	45 000	Cylinders
123	Brinell, 212 to 241	2400	0.20 to 0.30	37 500	Cylinder liners
124	Brinell, 187 to 228	....	....	......	Brake drums sprockets clutch plates
125	Brinell, 207 to 241	2500	0.24 to 0.34	37 500	
126	Brinell, 228 to 269	....	....	45 000	
127	Brinell, 187 to 228	....	....	......	Pistons

[a] For more complete information on physical properties, etc., see A.F.A.-A.S.T.M. Symposium on Cast Iron, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 115 (1933).

[b] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

[c] Brinell hardness tests are to be made using 10-mm. ball and 3000-kg. load.

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[1] See p. 713.

CHEMICAL COMPOSITION

Chemical Composition

8. (*a*) *Plain Cast Iron.*—The analyses in Table III are typical of plain cast iron but are not to be construed as required. With good foundry practice the physical properties given in Table I are usually met when the indicated analysis is used, although some variations from the suggested compositions may be necessary.

(*b*) *Alloy Cast Iron.*—The analyses in Table IV are typical of alloy cast iron but are not to be construed as required. With good foundry practice the physical properties given in Table II are usually met when the indicated analysis is used, although some variations from the suggested compositions may be necessary. Due to specific service requirements, costs, and the variables in foundry practice in influencing results, likewise, the possible variations in combinations of the alloying constituents, the kinds and amounts of the alloying elements used should be a matter of mutual agreement between the manufacturer and purchaser upon specific classes of castings. In general, one or more of the elements chromium, copper, molybdenum and nickel should be used.

TABLE III.—CHEMICAL COMPOSITION OF PLAIN CAST IRON.

No.[a]	Total Carbon, per cent	Combined Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, max., per cent	Silicon, per cent	Uses
110	3.45±0.15	......	0.60±0.10	0.30 max.	0.13	2.50±0.10	Miscellaneous soft iron castings
111	3.25±0.15	0.45±0.15	0.60±0.10	0.20 max.	0.13	2.20±0.10	Cylinders, flywheels, transmission cases
112	3.45±0.15	......	0.60±0.10	0.60±0.15	0.10	2.90±0.10	Piston rings

[a] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

TABLE IV.—CHEMICAL COMPOSITION OF ALLOY CAST IRON.

No.[a]	Total Carbon, per cent	Combined Carbon, per cent	Manganese, per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Uses
120	3.25±0.15	0.65±0.10	0.60±0.10	0.20	0.12	2.25±0.10	Cylinders
121	3.25±0.15	0.60±0.10	0.70±0.10	0.20	0.12	2.35±0.10	Cylinders
122	3.00±0.15	0.65±0.10	0.75±0.10	0.15	0.12	2.05±0.10	Cylinders
123	3.25±0.15	0.83±0.10	0.65±0.10	0.20	0.12	2.00±0.10	Cylinder liners
124	3.15±0.15	0.50±0.10	0.60±0.10	0.20	0.12	2.00±0.10	Brake drums, sprockets, clutch plates
125	3.25±0.15	0.65±0.10	0.60±0.10	0.20	0.12	2.00±0.10	
126	2.80±0.15	0.60±0.10	0.50±0.10	0.20	0.12	2.30±0.10	
127	3.40±0.15	0.40±0.10	0.60±0.10	0.20	0.12	2.30±0.10	Pistons

[a] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

Chemical Analyses

9. Analyses, especially in the case of combined carbon, will depend to a large extent upon the section of the casting from which the drillings are taken. In all cases the location from which the sample for chemical analysis is selected shall be a matter of mutual agreement between the manufacturer and purchaser.

WORKMANSHIP AND FINISH

Workmanship and Finish

10. (*a*) Castings shall represent good foundry practice.

(*b*) Castings shall be smooth and clean and shall be free from flaws and defects.

(*c*) In other respects the castings shall conform to special requirements mutually agreed to by the manufacturer and purchaser.

Machinability

11. Castings shall machine satisfactorily.

INSPECTION AND REJECTION

Inspection

12. The inspector representing the purchaser shall have free entry at all times to all parts of the manufacturer's work which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications.

Rejection

13. All castings which fail to conform to any of the provisions of these specifications shall be subject to rejection. Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified promptly.

TENTATIVE SPECIFICATIONS
FOR
GRAY-IRON CASTINGS[1]

A.S.T.M. Designation: A 48 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1935.

Scope

1. These specifications cover general gray-iron castings not covered by other existing specifications of the American Society for Testing Materials. These specifications apply to gray-iron castings where strength is a consideration. It is a purpose of these specifications to classify cast irons in respect to tensile strength.

PHYSICAL PROPERTIES AND TESTS

Tensile Strength Classification

2. Gray-iron castings conforming to these specifications shall be known and listed by classes (Notes 1, 2 and 3), according to minimum tensile strengths of test bars as follows:

CLASS	TENSILE STRENGTH, MINIMUM, LB. PER SQ. IN.
No. 20	20 000
No. 25	25 000
No. 30	30 000
No. 35	35 000
No. 40	40 000
No. 50	50 000
No. 60	60 000

Transverse Test

3. (*a*) Transverse tests shall be optional and the following minimum breaking loads are specified:

Transverse Test Bar	0.875 in. in Diameter	1.2 in. in Diameter	2.0 in. in Diameter
Span Length	12-in. Supports	18-in. Supports	24-in. Supports
CLASS	BREAKING LOAD AT CENTER, MIN., LB.	BREAKING LOAD AT CENTER, MIN., LB.	BREAKING LOAD AT CENTER, MIN., LB.
No. 20	900	1800	6 000
No. 25	1025	2000	6 800
No. 30	1150	2200	7 600
No. 35	1275	2400	8 300
No. 40	1400	2600	9 100
No. 50	1675	3000	10 300
No. 60	1925	3400	.....

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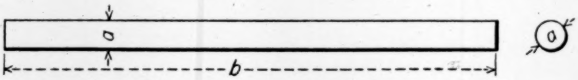
[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

These specifications are in effect a revision of, and replace the former Standard Specifications for Gray-Iron Castings (A.S.T.M. Designation: A 48 – 29) and Standard Specifications for High-Test Gray-Iron Castings (A.S.T.M. Designation: A 88 – 31), which standards were accordingly discontinued in 1933.

(*b*) By mutual agreement between the manufacturer and purchaser, deflection values in the transverse test may be specified (Note 4).

(*c*) The transverse breaking loads specified in Paragraph (*a*) are based on actual averages of transverse test loads for each class of casting. It is not implied by these specifications that the ratio of tensile strength to transverse load is constant. By agreement between the manufacturer and purchaser, tensile strength and transverse tests may be made and a range of transverse values determined. These values will then supersede the values specified in Paragraph (*a*).

(*d*) When an iron is specified by class (No. 20, No. 25, etc.) and the transverse test bar fails to meet the load requirements specified in Paragraph (*a*), then the manufacturer shall have the right to have tested a tension test specimen machined from a broken end of the transverse bar. In the event that this tension specimen meets the requirements of the specified class, as given in Section 2, the class requirement shall be considered as having been met, irrespective of the transverse breaking load.



TRANSVERSE TEST BAR	DIMENSIONS DIAMETER (*a*)	 LENGTH (*b*)	DISTANCE BETWEEN SUPPORTS IN TRANSVERSE TEST
A	0.875 in.	15 in.	12 in.
B	1.20 in.	21 in.	18 in.
C	2.00 in.	27 in.	24 in.

FIG. 1.—Transverse Test Bars.

Test Bars

4. Test bars shall be cast separately from the casting. Three standard sizes of transverse test bars are available under these specifications as shown in Fig. 1 (Note 5). Tension test specimens shall be machined from the transverse test bars to the dimensions shown in Fig. 2.

Correlation of Test Bar and Casting

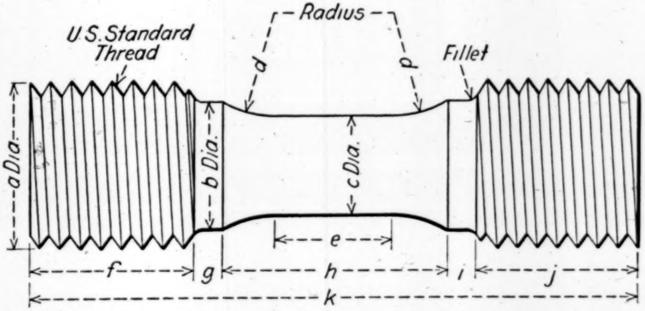
5. (*a*) The manufacturer and purchaser shall agree upon the controlling section of the casting. Then the corresponding test bar shall be used as follows:

CONTROLLING SECTION OF CASTING	TEST BAR	NOMINAL DIAMETER OF TEST BAR AS CAST
0.50 in. and under	*A*	0.875 in.
0.51 to 1.00 in.	*B*	1.20 in.
1.01 to 2.00 in.	*C*	2.00 in.
Over 2.00 in.	Test bar *C* may be used or a larger test bar may be used by mutual agreement between the manufacturer and purchaser.	

(*b*) The correlation in Paragraph (*a*) is only approximate and may need modification for complicated castings. The test bar size for a given casting may then be determined by mutual agreement between the manufacturer and purchaser.

Molding and Pouring Test Bars

6. Unless otherwise agreed upon by the manufacturer and purchaser, test bars shall be made under the same sand conditions as the castings (Notes 6 and 7). The bars shall be poured from a ladle or ladles of iron used to pour the castings. The test bars shall receive the same mechanical and thermal treatment as the castings. In the case of heat treatment, the test bars are to be treated adjacent to the castings they represent.



Dimension	Dimensions of Test Bars Test Bar *A*	 Test Bar *B*	 Test Bar *C*
a	$\frac{3}{4}$ in.	$1\frac{1}{8}$ in.	$1\frac{7}{8}$ in.
b	$\frac{5}{8}$ in.	$\frac{15}{16}$ in.	$1\frac{7}{16}$ in.
c	0.505 in.	0.800 in.	1.25 in.
d	1.00 in.	1.00 in.	2.00 in.
e[a]	Shall be equal or greater than *c* (diameter)		
f	1.00 in.	1.00 in.	$1\frac{3}{4}$ in.
g	0.25 in.	0.25 in.	$\frac{5}{16}$ in.
h, minimum	1.25 in.	1.50 in.	$2\frac{1}{4}$ in.
i	0.25 in.	0.25 in.	$\frac{5}{16}$ in.
j	1.00 in.	1.00 in.	$1\frac{3}{4}$ in.
k, minimum	3.75 in.	4.00 in.	$6\frac{3}{8}$ in.

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[a] Length of parallel.

FIG. 2.—Tension Test Specimens Machined from Transverse Test Bar.

Tensile Strength Test Procedure

7. Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is recommended (Note 8).

Transverse Test Procedure

8. The transverse test shall be made on the bar as cast with central loading between supports. Corrections shall be made for sizes of bars as shown in Table I. Controlling dimensions shall be the diameter of the bar at the fracture. The rate of application of the load shall be such that

fracture is produced in not less than 15 sec. for the 0.875-in. diameter bar; 20 sec. for the 1.2-in. diameter bar; and 40 sec. for the 2.0-in. diameter bar.

Number of Tests

9. The manufacturer shall prepare and furnish all test bars as agreed upon. Two or more test bars shall be cast.

Retests

10. (*a*) If a faulty or unsound test bar gives a result not in accord with the specifications, the result shall be disregarded and another test made.

(*b*) In case of failure of a test bar to meet the specifications, a retest may be made. If the retest fails, the castings shall be rejected, except as provided for in Paragraph (*c*).

(*c*) As provided for in Section 3 (*d*), when the transverse test bars fail to meet the specification requirements, tension test specimens may be machined from the broken ends of the transverse test bar. If the tension specimen meets the requirements of the specified class, the castings shall be accepted.

TABLE I.—CORRECTION FACTORS FOR TRANSVERSE TEST BARS.

In order to correct to the standard diameter, the breaking load and deflection obtained in testing the bar shall be divided by the respective correction factors.

0.875-in. Diameter Bar			1.20-in. Diameter Bar			2.00-in. Diameter Bar		
Diameter of Test Bars, in.	Correction Factor		Diameter of Test Bars, in.	Correction Factor		Diameter of Test Bars, in.	Correction Factor	
	Load	Deflection		Load	Deflection		Load	Deflection
0.825	0.838	1.061	1.10	0.770	1.091	1.90	0.857	1.053
0.830	0.853	1.054	1.11	0.791	1.081	1.91	0.871	1.047
0.835	0.869	1.048	1.12	0.813	1.071	1.92	0.885	1.042
0.840	0.885	1.042	1.13	0.835	1.062	1.93	0.899	1.037
0.845	0.900	1.036	1.14	0.857	1.053	1.94	0.913	1.032
0.850	0.916	1.029	1.15	0.880	1.043	1.95	0.927	1.026
0.855	0.933	1.023	1.16	0.903	1.034	1.96	0.941	1.021
0.860	0.949	1.017	1.17	0.927	1.026	1.97	0.955	1.015
0.865	0.966	1.012	1.18	0.951	1.017	1.98	0.970	1.010
0.870	0.983	1.006	1.19	0.975	1.009	1.99	0.985	1.005
0.875	1.000	1.000	1.20	1.000	1.000	2.00	1.000	1.000
0.880	1.017	0.994	1.21	1.025	0.992	2.01	1.015	0.995
0.885	1.034	0.989	1.22	1.051	0.984	2.02	1.030	0.990
0.890	1.051	0.983	1.23	1.077	0.976	2.03	1.046	0.985
0.895	1.069	0.978	1.24	1.103	0.968	2.04	1.061	0.980
0.900	1.087	0.972	1.25	1.130	0.960	2.05	1.076	0.976
0.905	1.106	0.967	1.26	1.158	0.952	2.06	1.092	0.972
0.910	1.125	0.962	1.27	1.185	0.945	2.07	1.109	0.967
0.915	1.143	0.956	1.28	1.214	0.938	2.08	1.125	0.962
0.920	1.162	0.951	1.29	1.242	0.930	2.09	1.141	0.957
0.925	1.181	0.946	1.30	1.271	0.923	2.10	1.158	0.952

CHEMICAL COMPOSITION

Chemical Analysis

11. It is the intent of these specifications to subordinate chemical composition to physical properties. By agreement between the manu-

facturer and purchaser, the quantities of any chemical elements in the cast iron may be specified.

WORKMANSHIP AND FINISH

Workmanship and Finish

12. The castings shall be true to pattern and free from cracks, gas holes, flaws and excessive shrinkage. Surfaces of the castings shall be free from burnt-on sand and shall be reasonably smooth. Runners, risers, fins and other cast-on pieces shall be removed. In other respects the castings shall conform to whatever points may be specially agreed upon between the manufacturer and purchaser.

INSPECTION

Inspection

13. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

CERTIFICATION

Certification

14. Upon request of the buyer, the manufacturer shall be prepared to certify that his product conforms to the requirements of these specifications.

EXPLANATORY NOTES

NOTE 1.—Classes Nos. 20, 25 and 30 cover the ordinary grades of gray cast iron. Classes Nos. 35, 40, 50 and 60 would be considered high-strength irons, particularly in medium and heavy sections.

NOTE 2.—The higher-strength irons are usually more expensive to produce because of the following:

(*a*) Special melting methods;
(*b*) Possible use of expensive alloys; and
(*c*) Changed practice in molding and pouring.
(*d*) Improved technique and supervision.

NOTE 3.—In general, the higher-strength irons are more difficult to machine, also more difficult to produce in heavy sections. Consequently, specifying a stronger cast iron than is needed may result in unnecessarily increased costs in producing the casting and in machining.

NOTE 4.—In the transverse test, it is recommended that the deflections at fracture be recorded and reported.

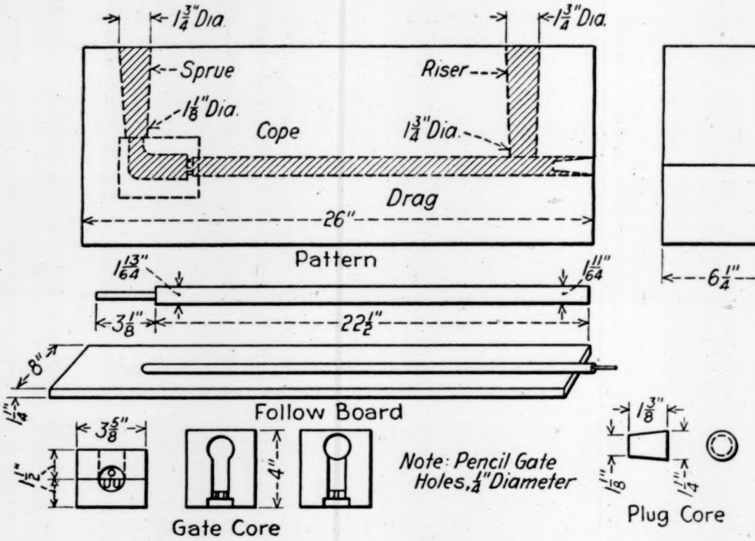
1¾" Dia.
1¾" Dia.
Sprue
Riser
1⅛" Dia.
Cope
1¾" Dia.
Drag
26"
6"
4"
6¼"
Pattern
1 13/64"
1 11/64"
3⅛"
22½"
8"
¼"
Follow Board
3⅝"
1½"
4"
Gate Core
Note: Pencil Gate Holes, ¼" Diameter
1⅜"
1⅛"
1¼"
Plug Core

FIG. A1.—Transverse Test Bar, 1.20-in. Diameter, Cast Horizontally.

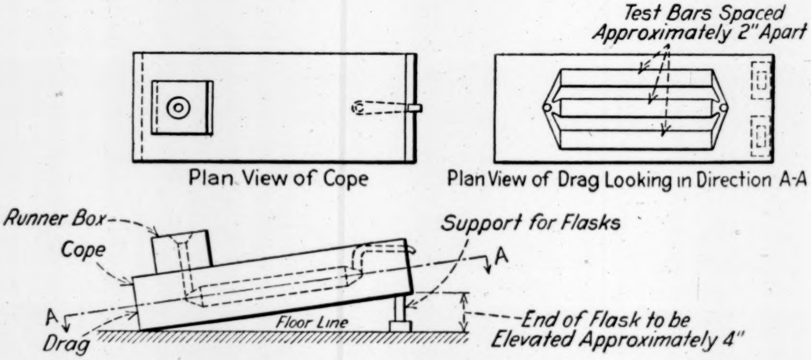
Test Bars Spaced Approximately 2" Apart
Plan View of Cope
Plan View of Drag Looking in Direction A-A
Runner Box
Cope
Support for Flasks
A
A
Drag
Floor Line
End of Flask to be Elevated Approximately 4"

FIG. A2.—Test Bar Cast on Incline.
Arrangement of Flasks for Casting Test Bars.

The modulus of rupture for any bar tested under these specifications can be ascertained by application of the following formula:

$$\text{Modulus of Rupture} = \frac{2.546\, L\, S}{D^3}$$

where L = the span length or distance between supports in inches;
S = the breaking load in pounds, and
D = the diameter of the test bar in inches.

Note 5.—Test bars shall be plain, cylindrical shapes as shown in Fig. 1. Where bars are cast on end, allowance for draft may be made. However, the diameter at the center of the length must correspond to the nominal diameter, within the following permissible variations:

	Permissible Variations
Bar *A*	± 0.05 in.
Bar *B*	± 0.10 in.
Bar *C*	± 0.10 in.

Tension test specimens "cast to size" are not recognized in these specifications.

Note 6.—A sound test bar is desired. Several methods of making transverse test bars are shown in Figs. A1, A2 and A3. All of these methods have been used and found to produce satisfactory results. Another method of making a transverse test bar is shown in Fig. 1 of the Standard Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (A.S.T.M. Designation: A 124) of the American Society for Testing Materials.[1]

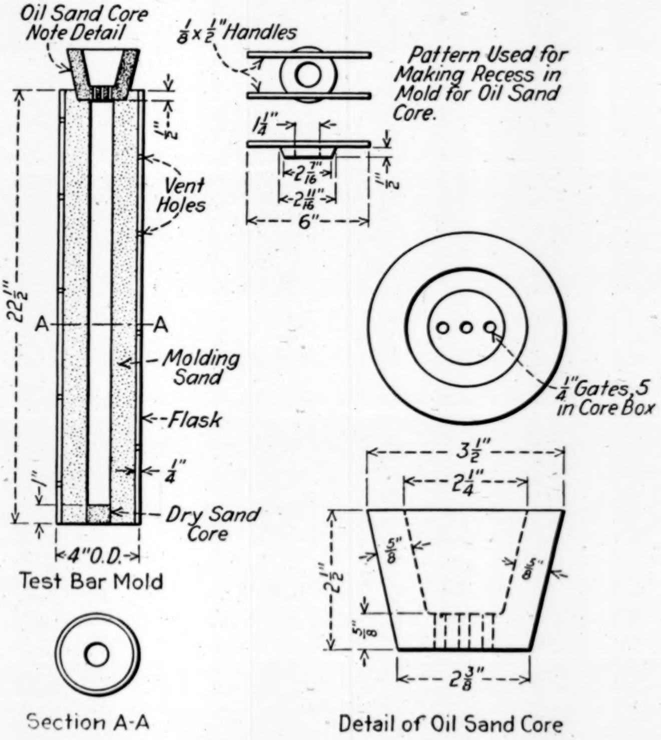
Oil Sand Core
Note Detail
1/8 x 1/2" Handles
Pattern Used for Making Recess in Mold for Oil Sand Core.
1/2"
Vent Holes
22 1/2"
A
A
Molding Sand
Flask
1/4"
1"
Dry Sand Core
4" O.D.
Test Bar Mold
1 1/4"
2 7/16"
2 11/16"
6"
1/2"
1/4" Gates, 5 in Core Box
3 1/2"
2 1/4"
5/8"
5/8"
2 1/2"
5/8"
2 3/8"
Section A-A
Detail of Oil Sand Core

Fig. A3.—Transverse Test Bar Cast Vertically.

Note 7.—Test bars shall not be cleaned by tumbling unless the castings are so cleaned, or unless mutually agreed upon by the manufacturer and purchaser.

Note 8.—The use of ball and socket holders in the tensile strength test is recommended. Tests made under conditions where eccentric loadings may occur will give erroneous results.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 496.

TENTATIVE SPECIFICATIONS
FOR
CAST-IRON CULVERT PIPE[1]

A.S.T.M. Designation: A 142 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1932; Revised, 1934, 1935.

Scope. 1. These specifications cover cast-iron pipe intended for use in the construction of culverts.

Classes. 2. These specifications cover three classes of pipe: namely, Standard Cast-Iron Culvert Pipe; Heavy Cast-Iron Culvert Pipe, and Extra-Heavy Cast-Iron Culvert Pipe.

Type of Pipe. 3. (*a*) Each length of pipe shall be cast as a unit and shall have a full circular cross-section with outside and inside circumferences concentric. Unless otherwise specified, the pipe may be smooth, corrugated or ribbed.

(*b*) The pipe shall be provided with suitable devices, such as hub ends or interlocking ends, to prevent displacement at joints.

MANUFACTURE

Material. 4. The pipe shall be manufactured of cast iron of good quality and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to admit satisfactorily of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola, air-furnace, or electric furnace.

Casting. 5. Pipe may be cast either vertically or horizontally in dry or green-sand molds or by centrifugal processes.

Coating. 6. (*a*) All pipe shall be completely coated inside and out by immersion in coal-tar pitch varnish to which sufficient oil shall have been added to make a smooth coating, tough and tenacious when cold, and not tacky nor brittle nor with any tendency to scale off.

(*b*) Prior to dipping, the pipe shall be thoroughly cleaned of rust, loose scale, grease and dirt.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-3 on Cast Iron.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

7. (*a*) The iron shall conform to the following ladle analysis requirements as to chemical composition:

Phosphorus, maximum, per cent	0.90
Sulfur, maximum, per cent	0.12

(*b*) The metal in the barrel of the finished pipe shall contain not more than 0.90 per cent of combined carbon. The test sample for the determination of combined carbon shall be composed of drillings representative of the full thickness of the pipe barrel.

(*c*) The manufacturer shall maintain a daily record of chemical analyses, and the portions of this record which concern pipe ordered by a purchaser shall be open to the inspection of the purchaser at all times.

PHYSICAL PROPERTIES AND TESTS

Strength Requirements.

8. (*a*) The pipe shall not fail and shall develop no cracks when tested under the following loads by the three-edge-bearing method:

CLASS OF PIPE	LOAD, LB. PER FOOT, OF LAYING LENGTH
Standard pipe	2000D
Heavy pipe	3000D
Extra-heavy pipe	4000D

NOTE.—D = nominal inside diameter of pipe in feet.

(*b*) Pipe specimens tested for strength shall not be tested to destruction if they will sustain, without cracking, a load 10 per cent in excess of the specified load. If the purchaser desires tests to destruction he shall specify on the order the number of such tests which will be required.

Three-Edge-Bearing Method.

9. (*a*) *Smooth Pipe.*—The lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ in. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical faces spaced at a distance apart not less than ½ in. nor more than 1 in. for each foot of nominal pipe diameter, with a minimum spacing of 1 in. for any size of pipe. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of the outside of the barrel of the pipe exclusive of the bell, if any. The pipe shall be placed symmetrically between the two bearings and the center of the application of load shall be at the center of the length of pipe, as illustrated in Figs. 1 and 2. In testing pipe which is "out of line" the

lines of the bearings chosen shall be from those which appear to give the most favorable conditions for fair test. In testing pipe, the specimen shall be placed so that the upper bearing will be along the thinnest element.

(*b*) *Corrugated or Ribbed Pipe.*—For corrugated or ribbed pipe the requirements for the three-edge-bearing method shall be the same as described in Paragraph (*a*) for smooth pipe. In the case of corrugated pipe, the bearing blocks shall be placed in contact with the outside crests of the corrugations. In the case of ribbed pipe, the bearing blocks shall be placed in contact with the tops of the transverse ribs. If the ribbed pipe has longitudinal ribs, the pipe shall be placed so that the bearing blocks will be, as nearly as possible, midway between the longitudinal ribs.

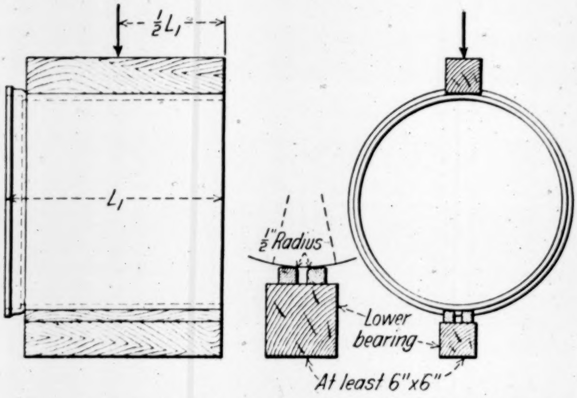

FIG. 1.—Three-Edge Bearings for Pipe with Bell End.

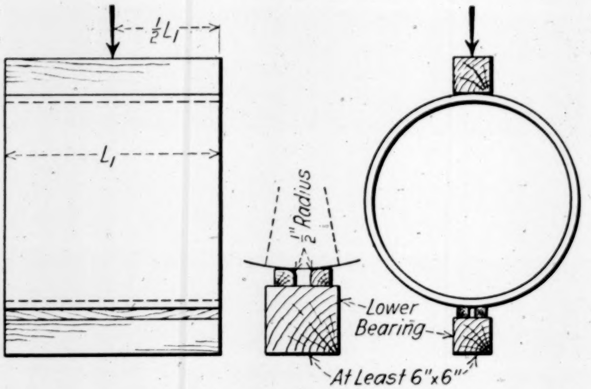

FIG. 2.—Three-Edge Bearings for Pipe Without Bell End.

Testing Apparatus. 10. Any mechanically driven or hand-power device, which meets the following requirements, may be used:

(*a*) It shall be substantially built and rigid throughout so that the distribution of the load to the specimen will not be affected appreciably by the deformation or yielding of any part.

(*b*) It shall provide for an approximately continuous application of load by means of a head which, during the test, moves at an approximately uniform rate not to exceed:

0.05 in. per minute for pipe less than 24 in. in diameter
0.10 in. per minute for pipe 24 to 36 in. in diameter
0.20 in per minute for pipe more than 36 in. in diameter

(*c*) It shall provide means for the determination of load with an error not greater than 2 per cent.

Number of Tests.

11. The purchaser may require strength tests in such numbers as he may deem necessary, provided that if the pipe meets the requirements as to shell thickness and weight, the number of specimens tested shall not exceed three pipe or 5 per cent, whichever may be larger, of each size and class ordered. In placing an order the purchaser shall specify the number of strength tests which will be required.

Selection of Test Specimens.

12. All pipe for purpose of tests shall be selected at random by the purchaser from the stock of the manufacturer, or from the pipe as delivered to the work, and shall be pipe which would not otherwise be rejected under these specifications.

Length of Test Specimens.

13. The laying length of test specimens of pipe shall be not less than 3 nor more than 4 ft. If the manufacturer proposes to furnish, for use in the work, pipe having a length greater than 4 ft., he shall furnish for the required tests a sufficient number of test specimens of the required length.

Testing and Disposal of Test Specimens.

14. Pipe specimens shall be tested under a load 10 per cent in excess of the load specified for the particular class of pipe. Shipments represented by specimens which sustain the specified load without the development of cracks shall be accepted as fulfilling the strength requirements. Specimens of pipe which meet all other requirements of the specifications and which sustain a load 10 per cent in excess of that specified without the development of cracks shall be accepted for use. The cost of specimens which fail to sustain the specified load, or a load 10 per cent in excess of that specified, shall be borne by the manufacturer.

NOTE.—It is recommended that a test specimen which has been accepted for use be marked with a suitable identification symbol and be installed in the culvert structure in such location as will subject it to the least severe loading.

Retests.

15. Pipe shall be acceptable under the strength tests when all test specimens fulfill the strength test requirements. Should any pipe fail to meet the test requirements, then the manufacturer will

be allowed a retest on two similar specimens for each specimen that failed, and the pipe shall be acceptable only when all of these retest specimens fulfill the test requirements. No further retests shall be permitted.

SIZES, WEIGHTS AND PERMISSIBLE VARIATIONS

Diameter.

16. (*a*) The minimum nominal diameter of pipe shall be 12 in.

(*b*) The minimum inside diameter of any pipe shall be not less than the nominal diameter by more than $\frac{1}{8}$ in.

TABLE I.—DIMENSIONS AND WEIGHTS OF SMOOTH CAST-IRON CULVERT PIPE.

Nominal Diameter, in.	Standard Pipe (2000*D*)		Heavy Pipe (3000*D*)		Extra-Heavy Pipe (4000*D*)	
	Nominal Thickness, in.	Nominal Weight per Foot of Barrel, lb.[a]	Nominal Thickness, in	Nominal Weight per Foot of Barrel, lb.[a]	Nominal Thickness, in.	Nominal Weight per Foot of Barrel, lb.[a]
12	0.37	45	0.37	45	0.40	49
14	0.37	52	0.40	57	0.46	65
16	0.40	64	0.46	74	0.53	86
18	0.42	76	0.52	95	0.60	110
20	0.47	94	0.57	115	0.66	134
24	0.56	135	0.69	167	0.80	195
30	0.70	211	0.86	261	1.00	304
36	0.84	304	1.03	374	1.20	438
42	0.98	414	1.20	509	1.40	597
48	1.12	540	1.38	669	1.60	779

[a] All weight values are per foot of barrel exclusive of hub.

TABLE II.—DIMENSIONS AND WEIGHTS OF CORRUGATED CAST-IRON CULVERT PIPE AND RIBBED CAST-IRON CULVERT PIPE.

	STANDARD PIPE (2000*D*)	
NOMINAL DIAMETER, IN.	NOMINAL THICKNESS, IN.	NOMINAL WEIGHT PER FOOT OF BARREL, LB.
15	0.25	45
18	0.25	50
24	0.31	85
30	0.38	125
36	0.44	165

Length.

17. Unless otherwise specified, pipe shall have a minimum laying length of 3 ft.

Dimensions and Weight.

18. (*a*) The shell thickness and the weights per linear foot for pipe of the various classes shall conform to the requirements given in Tables I and II.

(*b*) The shell thickness at any point shall be not more than 15 per cent under the thickness specified in Tables I and II.

(*c*) The weight of any section of pipe shall be not more than 5 per cent under the weight specified in Tables I and II.

Waiver of Strength Tests.

19. After the strength, shell thickness and weight of pipe of a particular class and size furnished by the manufacturer has been established by tests, the purchaser may elect to waive further strength tests and to accept pipe of that particular class, size and manufacture on the basis of the shell thickness and weight thus established, subject to the tolerances specified in Section 18 (*b*) and (*c*). Under these conditions the acceptability of the larger sizes of pipe shall not be based on the results of strength tests on smaller sizes.

WORKMANSHIP AND FINISH

Character of Castings.

20. (*a*) Pipe shall be practically straight and of true circular cross-section. They shall be sound, smooth and free from cracks, scales, lumps, blisters, sand holes, "cold shuts," or other defects which would render them unfit for the use intended.

(*b*) All pipe shall be carefully examined for defects and sounded with a hammer before shipment. No fillings with metal, cement or other material, or so-called "burning on" of iron will be permitted.

WEIGHING AND MARKING

Weighing.

21. If required by the purchaser, each pipe shall be weighed and, after coating, the weight plainly marked thereon with white paint.

Marking.

22. The brand of the manufacturer shall be legibly stamped-in or cast or stencilled on the metal of each pipe.

INSPECTION AND REJECTION

Inspection.

23. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities including labor to satisfy him that the pipe are being furnished in accordance with these specifications. All tests and inspections shall, if possible, be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser reserves the right, if deemed necessary, to inspect and test the pipe after delivery on the work.

Rejection.

24. (*a*) All pipes which fail to conform to any of the provisions of these specifications shall be subject to rejection.

(*b*) Pipes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified promptly.

TENTATIVE DEFINITIONS OF TERMS, WITH UNITS AND SYMBOLS, RELATING TO MAGNETIC TESTING[1]

A.S.T.M. Designation: A 127 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Definitions of Units

Gauss (*Maxwell per square centimeter*).—The induction in a magnetic field of such uniform cross-sectional value that when reduced at a uniform rate in one second from its initial value to zero there is induced in a conductor linked with the field one c.g.s. unit of electromotive force per square centimeter cross-sectional area of the field.

Gilbert.—The magnetomotive force between two points on a line of uniform magnetizing force when the product of the length of the line in centimeters and the magnetizing force in oersteds is unity.

Maxwell.—The flux through a surface of uniform induction when the product of the induction in gausses and the surface area in square centimeters is unity.

Oersted (*Gilbert per centimeter*).—The magnetizing force at the center of a solenoid of n turns per centimeter and of such length that end effects are negligible when the current in the solenoid has a value in amperes such that the current $I = \frac{1}{0.4\pi\, n}$.

Note.—At the center of such a solenoid $H = 0.4\pi nI$.

General Definitions

In the following list of definitions the term defined is given first followed in parenthesis by any optional alternative terms which may be used when the context clearly indicates the intended conception. The symbol for the quantity is then given wherever such symbol is in use, followed by the definition of the standard term.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee A-6 on Magnetic Properties.

These tentative definitions are in effect a tentative revision of, and are intended to supersede when adopted, the present Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A.S.T.M. Designation: A 127 – 34), 1934 Supplement to Book of A.S.T.M. Standards, p. 69.

Aging, of magnetic materials.—The normal or accelerated change in magnetic properties of a magnetic material under continued normal or specified artificial aging conditions.

NOTE.—When used in reference to core loss, this term, unless otherwise modified, implies an increase in loss. When used in reference to permeability or remanence, the term, in a positive sense, indicates a decrease in these quantities.

Coercive Force, H_c.—The value of the magnetizing force at which the induction is zero for a material which is in a symmetrically cyclicly magnetized condition.

UNIT: *Oersted.*

Coercivity.—That property of a material measured by the coercive force corresponding to the saturation induction for the material.

UNIT: *Oersted.*

Core Loss Aging Coefficient.—The percentage change in the standard core loss after continued heating at 100 C. for 600 hours.

NOTE.—The sign should be positive if there is an increase in loss.

Core Loss (Iron Loss), P.—The power expended in a magnetic material subjected to a varying induction.

Core Loss, Standard, $P_{B/f}$.—The total power in watts per kilogram expended in the magnetic material which is subjected to a harmonically varying induction of a specified maximum value B and of a specified frequency f.

Cyclicly Magnetized Condition.—See Normal Induction.

Diamagnetic Material.—A material having a permeability less than that of a vacuum.

Differential Permeability.—See Permeability, Differential.

Eddy Current Loss, P_e.—That part of the core loss due to currents circulating in the magnetic material as a result of electromotive forces induced by the varying induction.

Ferric Induction.—See Intrinsic Induction.

Ferromagnetic Material.—A material having a permeability considerably greater than that of a vacuum. In general, the permeability of a ferromagnetic material is dependent upon the magnetizing force.

Field.—See Magnetic Field.

Flux.—See Magnetic Flux.

Hysteresis Loss, P_h.—That part of the core loss represented by the energy converted into heat as a result of magnetic hysteresis.

Hysteresis, Magnetic.—That property of a material by virtue of which the magnetic induction for a given magnetizing force depends upon the previous conditions of magnetization.

Incremental Permeability.—See Permeability, Incremental.

Induction.—See Intrinsic Induction; Magnetic Induction; Normal Induction; Residual Induction; Saturation Induction.

Initial Permeability.—See Permeability, Initial.

Intrinsic Induction Curve (*Magnetic Saturation Curve*).—A curve depicting the relation between intrinsic induction and magnetizing force.

Intrinsic Induction in a Ferromagnetic Material (*Ferric Induction*), B_i.—For a given value of the magnetizing force, the excess of the normal induction in the material over that in vacuum.

$$B_i = B - H$$

UNIT: *Gauss.*

Intrinsic Permeability.—See Permeability, Intrinsic.

Iron Loss.—See Core Loss.

Linkage.—The product of the flux in maxwells and the number of turns in a coil or winding linked therewith.

Magnetic Circuit.—A closed path of magnetic flux.

Magnetic Field (*Field*).—In a given region of space, the totality of values of the magnetizing forces throughout the region.

NOTE.—This term is also used to denote the region itself.

Magnetic Flux (*Flux*), ϕ.—The surface integral of the magnetic induction over a given area.

UNIT: *Maxwell.*

Magnetic Flux Density.—See Magnetic Induction.

Magnetic Force.—See Magnetizing Force.

Magnetic Hysteresis.—See Hysteresis, Magnetic.

Magnetic Induction (*Magnetic Flux Density*), B.—The vector magnetic quantity accompanying and having the same direction at a point in an isotropic medium as the magnetizing force at the point, but having a magnitude which is dependent upon the properties of the medium.

NOTE.—The magnitude is measured by the electromotive force produced in an electric circuit when the circuit is linked with the induction at a definite time rate. Thus:

$$e = N\frac{dB}{dt}$$

where e is the electromotive force produced in a circuit which is linked N times with the magnetic field of unit cross-sectional area and of uniform induction B.

UNIT: *Gauss.*

Magnetic Intensity.—See Magnetizing Force.

Magnetic Material.—See Diamagnetic Material; Ferromagnetic Material; Paramagnetic Material.

Magnetic Potential Difference.—The line integral of magnetizing force between two points in a magnetic field.

NOTE.—The value of the magnetic potential difference between two points in the magnetic field of a current depends upon the path over which the integral is taken.

Magnetic Saturation Curve.—See Intrinsic Induction Curve.

Magnetician.—One skilled in the art of making magnetic measurements.

Magnetizing Force (Magnetic Intensity, Magnetic Force), H.—That vector magnetic quantity arising from electric currents which at a given point depends only on the position of the point relative to the currents and on their magnitude. The magnetizing force H_i at a point P arising from a current I in an electric circuit is given by the equation:

$$H_i = I\int\frac{[r \times ds]}{r^3}$$

where r is a vector extending from an element ds of the circuit to the point P; $[r \times ds]$ is the vector product of r and ds; and the integral is taken completely around the circuit.

NOTE.—Magnetizing force also arises from magnetized bodies.

UNIT: *Oersted.*

Magnetomotive Force, $\mathcal{F}$.—In any closed path in a magnetic field, the line integral of the magnetizing force around the path.

NOTE.—In any path, the magnetomotive force resulting from a current is directly proportional to the current which links the path. The magnetomotive force $\mathcal{F}$ around any path is given in gilberts by the equation:

$$\mathcal{F} = \frac{4\pi NI}{10}$$

where N is the number of times the electric circuit links the path, and I is the current in amperes.

When a current of I amperes is flowing in a circuit of N turns, $\mathcal{F} = 0.4\pi NI$.

UNIT: *Gilbert.*

Normal Induction Curve.—A curve depicting the relation between normal induction and magnetizing force.

Normal Induction in a Ferromagnetic Material (*Normal Induction*), *B.*—The limiting induction either positive or negative in a material which is in a symmetrically cyclicly magnetized condition.

NOTE.—A magnetic material is in a *cyclicly magnetized condition* when it has been under the influence of a magnetizing force varying between two specific limits until the successive hysteresis loops retrace the preceding ones.

A magnetic material is in a *symmetrically cyclicly magnetized condition* when it is cyclicly magnetized and the limits of the applied magnetizing forces are equal and of opposite sign, also the limits of induction are equal and of opposite sign.

UNIT: *Gauss.*

Normal Permeability.—See Permeability, Normal.

Paramagnetic Material.—A material having a permeability slightly greater than that of a vacuum and approximately independent of the magnetizing force.

Permeability, μ.—That property of an isotropic medium which determines, under specified conditions, the magnitude relation between magnetic induction and magnetizing force in the medium.

NOTE.—Under the specified conditions, permeability is measured as the ratio of the magnetic induction to the magnetizing force. In terms of the units of magnetic induction and magnetizing force as defined, the permeability of empty space is unity.

Permeability, Differential, μ_d.—The ratio of the positive increase of normal induction to the positive increase of magnetizing force when these increases are vanishingly small.

Permeability, Incremental, μ_Δ.—The ratio of the cyclic change in induction to the corresponding cyclic change in magnetizing force when the mean induction differs from zero.

Permeability, Initial, μ_o.—The normal permeability when both the magnetizing force and the induction are vanishingly small.

Permeability, Intrinsic, μ_i.—The ratio of the intrinsic induction to the corresponding magnetizing force.

Permeability, Normal, μ.—The ratio of the normal induction to the corresponding magnetizing force.

Permeability, Reversible, μ_r.—The incremental permeability when the change in induction is vanishingly small.

Permeability, Space.—That factor which expresses the ratio of magnetic induction to magnetizing force in vacuum.

NOTE.—In the c.g.s. electromagnetic system of units the permeability of a vacuum is arbitrarily taken as unity.

Permeance, $\mathscr{P}$.—In a portion of a magnetic circuit extending between two equipotential surfaces, the ratio of the flux through any cross-section to the magnetic potential difference between the surfaces when taken within the portion under consideration.

NOTE.—Permeance, $\mathscr{P} = \frac{\phi}{\mathscr{F}}$ is equivalent to $\frac{\mu A}{l}$ for uniform μ.

where μ = permeability;
A = area in square centimeters; and
l = length in centimeters.

Reluctance, $\mathscr{R}$.—The reciprocal of permeance.

NOTE.—Reluctance, $\mathscr{R} = \frac{\mathscr{F}}{\phi}$ is equivalent to $\frac{l}{\mu A}$ for uniform μ.

Reluctivity.—The reciprocal of the permeability of a medium.

Remanence.—The magnetic induction remaining in a magnetic circuit after the removal of an applied magnetizing force.

NOTE.—If there is an air gap in the magnetic circuit, the remanence will be less than the residual induction.

UNIT: *Gauss.*

Residual Induction, B_r.—The value of the magnetic induction at which the magnetizing force is zero for a material which is in a symmetrically cyclicly magnetized condition.

UNIT: *Gauss.*

Retentivity.—That property of a material measured by the residual induction corresponding to the saturation induction for the material.

UNIT: *Gauss.*

Reversible Permeability.—See Permeability, Reversible.

Saturation Induction, B_s.—The maximum intrinsic induction possible in a material.

UNIT: *Gauss.*

Space Permeability.—See Permeability, Space.

Standard Core Loss.—See Core Loss, Standard.

TENTATIVE SPECIFICATIONS

FOR

WROUGHT PHOSPHOR BRONZE BEARINGS AND EXPANSION PLATES FOR BRIDGES AND STRUCTURES[1]

A.S.T.M. Designation: B 100 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover two classes of wrought bronze bearing metals for movable bridges and structures, as follows:

Class A.—For contact with hardened steel disks under pressures over 1500 lb. per sq. in., for example, bearing metals, expansion plates, etc., used in center-bearing swing bridges.

Class B.—For contact with soft steel at low speeds under pressures not over 1500 lb. per sq. in., for example, expansion plates, etc., trunnions and journals of bascule and lift bridges.

Material

2. (*a*) The bronze shall be a homogeneous alloy of copper and tin. The copper shall conform to the requirements of the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5), or the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars, "high-resistance lake" grade (A.S.T.M. Designation: B 4) of the American Society for Testing Materials.[2] The bronze shall be made from new metal, except that scrap of known composition may be used.

(*b*) The bronze shall be manufactured by the rolling and annealing process, and it may be furnished in either the rolled or annealed condition, as required.

Chemical Composition

3. The bronze shall conform to the following requirements as to chemical composition:

	CLASS A	CLASS B
Copper, per cent	remainder	remainder
Tin, min., per cent	7.0	3.5
Phosphorus, per cent	0.05 to 0.50	0.05 to 0.50
Copper plus tin plus phosphorus, min., per cent	99.50	99.50

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

[2] 1933 Book of A.S.T.M. Standards, Part I, pp. 573, 568.

Chemical Analysis

4. (*a*) An analysis shall be furnished by the manufacturer for each 2000 lb. of bronze or fraction thereof. The chemical composition as determined by the Standard Methods of Chemical Analysis of Bronze Bearing Metal (A.S.T.M. Designation: B 46) of the American Society for Testing Materials[1] shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

(*b*) The sample for chemical analysis shall consist of drillings, or millings taken from the plates selected for purpose of tests as specified in Sections 5 and 6, and shall be so taken as to accurately represent material from the full thickness of the plate. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the purchaser, one for the manufacturer and one for an umpire if necessary.

Physical Properties and Tests

5. The tension tests shall be standard for plates of all thicknesses, and acceptance or rejection in the case of plates less than $\frac{3}{4}$ in. in thickness shall be based only on the tensile strength and elongation values specified in Section 6. Plates $\frac{3}{4}$ in. or over in thickness may be accepted or rejected upon either the tension test or the compression test at the option of the purchaser when expressed in writing. For convenience in testing plates from $\frac{3}{4}$ to $\frac{1}{4}$ in. in thickness, the Brinell hardness test may be employed; for material under $\frac{1}{4}$ in. in thickness, the Rockwell hardness "B" scale ($\frac{1}{16}$-in. ball, 100-kg. load) may be used (Note).

NOTE.—In making hardness tests reference should be made to the Standard Methods of Brinell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 10)[2] and the Tentative Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18 – 33 T)[3] of the American Society for Testing Materials.

Physical Properties

6. (*a*) The bronze shall conform to the following requirements as to tensile or compressive properties. The Brinell and Rockwell hardness values are for informative purposes only.

PROPERTIES		CLASS A	CLASS B
Tension			
Tensile strength, lb. per sq. in.		72 000, min.	55 000 to 75 000
Elongation in 2 in., min., per cent		10	15
Compression			
Deformation limit, min., lb. per sq. in.		40 000	25 000
Permanent set under 100,000 lb. per sq. in., per cent[a]		2 to 12	6 to 20
Hardness	Plate $\frac{3}{4}$ to $\frac{1}{4}$ in. thick, Brinell number	140, min.	100 to 160
	Plate under $\frac{1}{4}$ in. thick, Rockwell number[b]	80, min.	45 to 85

[a] The variable height compression test specimen will require that the set limits shall be expressed as a percentage instead of in inches; thus, 0.001 in. per inch will become 0.10 per cent.

[b] Rockwell hardness test, B scale, $\frac{1}{16}$-in. ball, 100-kg. load.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 635.

[2] *Ibid.*, p. 942.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 967 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1377.

(*b*) The deformation limit in compression shall be determined as that load which produces a permanent set of 0.10 per cent in the compression test specimen described in Section 7 (*b*).

Test Specimens

7. (*a*) The tension test specimen and method of testing shall conform to the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

TABLE I.—PERMISSIBLE VARIATIONS IN THICKNESS, PLUS AND MINUS.

Thickness		Up to 6 in. in Width, inclusive	Over 6 to 9 in. in Width, inclusive	Over 9 to 14 in. in Width, inclusive	Over 14 to 20 in. in Width, inclusive
B. & S. Gage No.	Inch				
0000	0.4600	0.0043	0.0045	0.0047	0.0049
000	0.4096	0.0042	0.0044	0.0046	0.0048
00	0.3648	0.0041	0.0043	0.0045	0.0047
0	0.3249	0.0040	0.0042	0.0044	0.0046
1	0.2893	0.0039	0.0041	0.0043	0.0045
2	0.2576	0.0038	0.0040	0.0042	0.0044
3	0.2294	0.0037	0.0039	0.0041	0.0043
4	0.2043	0.0036	0.0038	0.0040	0.0042
5	0.1819	0.0035	0.0037	0.0039	0.0041
6	0.1620	0.0034	0.0036	0.0038	0.0040
7	0.1443	0.0033	0.0035	0.0037	0.0039
8	0.1285	0.0032	0.0034	0.0036	0.0038
9	0.1144	0.0031	0.0033	0.0035	0.0037
10	0.1019	0.0030	0.0032	0.0034	0.0036
11	0.0907	0.0029	0.0031	0.0033	0.0035
12	0.0808	0.0028	0.0030	0.0032	0.0034
13	0.0719	0.0027	0.0029	0.0031	0.0033
14	0.0640	0.0026	0.0028	0.0030	0.0032
15	0.0570	0.0025	0.0027	0.0029	0.0031
16	0.0508	0.0024	0.0026	0.0028	0.0030
17	0.0452	0.0023	0.0025	0.0027	0.0029
18	0.0403	0.0022	0.0024	0.0026	0.0028
19	0.0359	0.0021	0.0023	0.0025	0.0026
20	0.0320	0.0020	0.0021	0.0023	0.0024
21	0.0284	0.0019	0.0020	0.0021	0.0022
22	0.0253	0.0018	0.0019	0.0020	0.0021
23	0.0225	0.0017	0.0018	0.0019	0.0020
24	0.0201	0.0016	0.0017	0.0018	0.0019
25	0.0179	0.0015	0.0016	0.0017	0.0018
26	0.0159	0.0014	0.0015	0.0016	0.0017
27	0.0142	0.0013	0.0014	0.0015	0.0016
28	0.0126	0.0012	0.0013	0.0014	0.0015
29	0.0112	0.0011	0.0012	0.0013	0.0014
30	0.0100	0.0011	0.0012	0.0013	0.0014
31	0.0089	0.0010	0.0011	0.0012	0.0013
32	0.0079	0.0010	0.0011	0.0012	0.0013
33	0.0070	0.0009	0.0010	0.0011	0.0012
34	0.0063	0.0009	0.0010	0.0011	0.0012
35	0.0056	0.0008	0.0009	0.0010	0.0011
36	0.0050	0.0008	0.0009	0.0010	0.0011

(*b*) Compression test specimens shall be 1 sq. in. in cross-sectional area and $\frac{3}{4}$ to $1\frac{1}{2}$ in. in height.

Number of Tests

8. (*a*) One tension (or compression) test shall be made from each 2000 lb. of finished metal, or fraction thereof.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

Permissible Variations in Dimensions

9. (*a*) The standard method of specifying thickness shall be in Brown & Sharpe gage numbers. When the thickness is specified either in common or decimal fractions of an inch, the tolerances shall be those of the corresponding group of B. & S. gages, as shown in Table I.

(*b*) For plates heavier and wider than those covered in Table I, the percentage variation in weight shall be as follows:

	PERMISSIBLE VARIATION IN WEIGHT, PER CENT	
WIDTH	OVER	UNDER
Up to 48 in.	5	5
Over 48 to 60 in., inclusive	5	7
Over 60 in.	5	8

Finish

10. The plates shall be sound, clean and free from blowholes, porous places, cracks, and other defects that would be detrimental or injurious to their use for the purposes intended. The contact surfaces of the plates shall be smooth and level.

Inspection

11. At the option of the purchaser, inspection may be made at the manufacturer's works where the plates are made, or at the point at which they are received. If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

12. Plates which fail to conform to these specifications may be rejected, and if rejected, shall be replaced by the manufacturer, without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
BARE, STRANDED COPPER CABLE: HARD, MEDIUM-HARD, OR SOFT[1]

A.S.T.M. Designation: B 8 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These specifications cover bare, stranded cables made from round copper wires, for general use as electrical conductors.

Classes

(*b*) For the purposes of these specifications, conductors are classified as follows (Notes 1 and 2):

Class AA.—For bare cable.

Class A.—For weather-resistant (weatherproof), slow-burning, and slow-burning weather-resistant cables, and for bare cable where greater flexibility than is afforded by Class *AA* is required.

Class B.—For cable insulated with various materials such as rubber, paper, varnished cloth, etc., and for the cables indicated under Class *A* where greater flexibility is required.

Class C and *Class D*.—For cable where greater flexibility is required than is provided by Class *B* cable.

NOTE 1.—In these specifications only concentric-lay cable constructions are specifically designated. Bunched-strands, rope-lay, or other cable constructions should be specifically agreed upon by the manufacturer and purchaser when placing the order if other than concentric-lay cable is involved.

NOTE 2.—For definitions of terms relating to cable, reference should be made to the Definitions and General Standards for Wires and Cables (A.S.A. No. C8*a* - 1932) approved by the American Standards Association.

MANUFACTURE

Requirements for Wires

2. (*a*) The purchaser shall designate the type of wire to be used in the cable. Before stranding, the copper wire used shall meet all of the requirements of the following standards of the American Society for Testing Materials,[1] applicable to its class:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

These tentative specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard, or Soft (A.S.T.M. Designation: B 8 - 27), 1933 Book of A.S.T.M. Standards, Part I, p. 746.

Standard Specifications for Soft or Annealed Copper Wire (A.S.T.M. Designation: B 3)

Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (A.S.T.M. Designation: B 33)

Standard Specifications for Medium Hard-Drawn Copper Wire (A.S.T.M. Designation: B 2)

Standard Specifications for Hard-Drawn Copper Wire (A.S.T.M. Designation: B 1)

(*b*) In concentric-lay cables the central core shall be made of wire having the same quality and temper as the concentric layers, unless otherwise specified.

Brazes

3. Brazes shall not be permitted in hard-drawn or medium hard-drawn Class *AA* cables of seven wires or less. In other cables, brazes may be made in the wire when finished and ready for cabling. Such brazes shall be made in accordance with the best commercial practice. Brazes shall not be closer together than as shown in the following table:

NUMBER OF WIRES IN CABLE	HARD OR MEDIUM-HARD	SOFT
3	no brazes permitted	[a]
7 to 36, incl	50 ft.	[a]
37 to 60, incl	25 ft.	[a]
61 and over	5 ft.	[a]

[a] Cable may not be brazed as a unit.

Lay

4. The lay or pitch of a layer of wires in concentric cable shall be not less than ten nor more than sixteen times the outside diameter of that layer, except that for cables composed of 37 wires or more, this requirement shall apply only to the two outer layers. Cable furnished on one order shall have the same lay. The direction of lay of the outer layer may be either right or left-hand unless the direction of lay is specified by the purchaser. The direction of lay shall be reversed in successive layers unless specific instructions to the contrary are received from the purchaser.

Construction

5. The areas of cross-section, numbers and diameters of wires in the various classes of concentric-lay cables shall be as shown in Table I (Note 2).

PROPERTIES AND TESTS

Physical and Electrical Tests

6. (*a*) Tests for the physical and electrical properties of wires composing cables made from annealed copper wire or from tinned soft copper

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[1] 1933 Book of A.S.T.M. Standards, Part I, pp. 763 to 781.

wire may be made before stranding or on wires removed from the cable. In the latter case the maximum tensile strength permitted shall be increased 5 per cent and the minimum elongation permitted shall be reduced 5 per cent. Care must be taken to avoid mechanical injury of wire removed from cable for the purpose of testing.

TABLE I.—CONSTRUCTION REQUIREMENTS OF BARE CONCENTRIC-LAY COPPER CABLE.

Area of Cross-Section, circular mils	Size, American or B. & S. Wire Gage	Class *AA*		Class *A*		Class *B*		Class *C*		Class *D*	
		Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils
*5 000 000	....	....	....	169	172.0	217	151.8	271	135.8	271	135.8
4 500 000	....	....	....	169	163.2	217	144.0	271	128.9	271	128.9
4 000 000	....	....	....	169	153.8	217	135.8	271	121.5	271	121.5
3 500 000	....	....	....	127	166.0	169	143.8	217	127.0	271	113.6
*3 000 000	....	....	....	127	153.7	169	133.2	217	117.6	271	105.2
*2 500 000	....	....	....	91	165.7	127	140.3	169	121.6	217	107.3
*2 000 000	....	....	....	91	148.2	127	125.5	169	108.8	217	96.0
1 900 000	....	....	....	91	144.5	127	122.3	169	106.0	217	93.6
1 800 000	....	....	....	91	140.6	127	119.1	169	103.2	217	91.1
*1 750 000	....	....	....	91	138.7	127	117.4	169	101.8	217	89.8
1 700 000	....	....	....	91	136.7	127	115.7	169	100.3	217	88.6
1 600 000	....	....	....	91	132.6	127	112.2	169	97.3	217	85.9
*1 500 000	....	....	....	61	156.8	91	128.4	127	108.7	169	94.2
1 400 000	....	....	....	61	151.5	91	124.0	127	105.0	169	91.0
1 300 000	....	....	....	61	146.0	91	119.5	127	101.2	169	87.7
*1 250 000	....	....	....	61	143.1	91	117.2	127	99.2	169	86.0
1 200 000	....	....	....	61	140.3	91	114.8	127	97.2	169	84.3
1 100 000	....	....	....	61	134.3	91	109.9	127	93.1	169	80.7
*1 000 000	....	37	164.4	61	128.0	61	128.0	91	104.8	127	88.7
900 000	....	37	156.0	61	121.5	61	121.5	91	99.4	127	84.2
*800 000	....	37	147.0	61	114.5	61	114.5	91	93.8	127	79.4
*750 000	....	37	142.4	61	110.9	61	110.9	91	90.8	127	76.8
*700 000	....	37	137.5	61	107.1	61	107.1	91	87.7	127	74.2
650 000	....	37	132.5	61	103.2	61	103.2	91	84.5	127	71.5
*600 000	....	37	127.3	37	127.3	61[c]	99.2	91	81.2	127	68.7
550 000	....	37	121.9	37	121.9	61[d]	95.0	91	77.7	127	65.8
*500 000	....	19	162.2	37	116.2	37	116.2	61	90.5	91	74.1
450 000	....	19	153.9	37	110.3	37	110.3	61	85.9	91	70.3
*400 000	....	19	145.1	19	145.1	37	104.0	61	81.0	91	66.3
*350 000	....	12	170.7	19	135.7	37	97.3	61	75.7	91	62.0
*300 000	....	12	158.1	19	125.7	37	90.0	61	70.1	91	57.4
*250 000	....	12	144.3	19	114.7	37	82.2	61	64.0	91	52.4
*211 600	0000	7[a]	173.9	7[a]	173.9	19	105.5	37	75.6	61	58.9
*167 800	000	7[b]	154.8	7[b]	154.8	19	94.0	37	67.3	61	52.4
*133 100	00	7	137.9	7	137.9	19	83.7	37	60.0	61	46.7
*105 500	0	7	122.8	7	122.8	19	74.5	37	53.4	61	41.6
*83 690	1	3	167.0	7	109.3	19	66.4	37	47.6	61	37.0
*66 370	2	3	148.7	7	97.4	7	97.4	19	59.1	37	42.4
*52 640	3	3	132.5	7	86.7	7	86.7	19	52.6	37	37.7
*41 740	4	3	118.0	7	77.2	7	77.2	19	46.9	37	33.6
*33 100	5	....	....	....	....	7	68.8	19	41.7	37	29.9
*26 250	6	....	....	....	....	7	61.2	19	37.2	37	26.6
*20 820	7	....	....	....	....	7	54.5	19	33.1	37	23.7
*16 510	8	....	....	....	....	7	48.6	19	29.5	37	21.1
*13 090	9	....	....	....	....	7	43.2	19	26.2	37	18.8
*10 380	10	....	....	....	....	7	38.5	19	23.4	37	16.7
*6 530	12	....	....	....	....	7	30.5	19	18.5	37	13.3
*4 107	14	....	....	....	....	7	24.2	19	14.7	37	10.5
*2 583	16	....	....	....	....	7	19.2	19	11.7	....	....
*1 624	18	....	....	....	....	7	15.2	19	9.2	....	....
*1 022	20	....	....	....	....	7	12.1	19	7.3	....	....

* The sizes of cable which have been marked with an asterisk provide for one or more schedules of preferred series, and are commonly used in the industry. The sizes not marked are given simply as a matter of reference, and it is suggested that their use be discouraged.

[a] Optional construction for No. 0000 A.W.G. size in Class *AA* and Class *A* is 12 wires of 132.8 mils diameter.

[b] Optional construction for No. 000 A.W.G. size in Class *AA* and Class *A* is 12 wires of 118.3 mils diameter.

[c] Optional construction for 600,000-cir. mils size in Class *B* is 37 wires of 127.3 mils diameter.

[d] Optional construction for 550,000-cir. mils size in Class *B* is 37 wires of 121.9 mils diameter.

(*b*) Tests for the physical and electrical properties of wires composing cables made from hard-drawn or medium hard-drawn wire may be made before but not after stranding.

(*c*) At the option of the purchaser, tests on hard-drawn and medium hard-drawn wires before stranding may be waived, and completed hard-drawn and medium hard-drawn cables may be tested as a unit. The minimum tensile strength of bare cables so tested shall be 90 per cent of the total of the required minimum strengths of the component wires. The free length between grips of the test sample shall be not less than 24 in., and care shall be taken to insure that the wires in the cable are evenly gripped during the test (Note).

NOTE.—To test cable successfully as a unit requires an adequate means of gripping the ends of the test sample. Various means are available, such as a long tube or socket into which the cable may be soldered, or in which, after insertion, the cable may be swaged or pressed without serious distortion. Ordinary jaws or clamping devices are not usually suitable.

Weights and Area

7. (*a*) For the purpose of calculating weights, cross-sections, etc., the density of copper shall be taken as 8.89 g. per cu. cm. (0.321 lb. per cu. in.) at 20 C. (68 F.).

(*b*) The electrical resistance and mass of a stranded conductor are greater than the total of these characteristics of the wires composing the cable, depending upon the lay or pitch. Two per cent shall be taken as the standard increment of resistance and mass of concentric-lay cable. In cases where the lay is definitely known, the increment shall be calculated and not assumed.

Variation in Area

8. The area of cross-section of the completed cable shall be not less than 98 per cent of the area specified. The area of cross-section shall be considered to be the sum of the cross-sectional areas of its component wires when measured perpendicularly to their axes.

PACKING AND SHIPPING

Packing and Shipping

9. (*a*) Package sizes for cable shall be agreed upon in the placing of individual orders.

(*b*) The cable shall be protected against damage in ordinary handling and transportation.

INSPECTION

Inspection

10. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications.

TENTATIVE SPECIFICATIONS
FOR
BRONZE TROLLEY WIRE[1]

A.S.T.M. Designation: B 9 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover round and grooved bronze trolley wire.

MANUFACTURE

Material

2. The material used shall be bronze of such nature and composition[2] as to secure by proper treatment the qualities hereinafter specified for the finished wire. The copper used shall be electrolytic or low-resistance lake copper conforming in quality and purity to the requirements of either the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 5)[3] or of the Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (A.S.T.M. Designation: B 4)[4] of the American Society for Testing Materials.

Classes

3. Bronze of three qualities (Note) may be required, as follows:

Class A
Class B
Class C

NOTE.—Class *A* wire was formerly known as "high strength" bronze wire, and also has been known as 40 per cent conductivity bronze wire.

Class *B* was formerly known as "medium strength" bronze wire, and also has been known as 65 per cent conductivity bronze wire.

Class *C* wire has a strength intermediate between Class *A* and Class *B* wire, and is of lower resistivity than either, its value of conductivity being 80 per cent.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-1 on Copper Wire.

These tentative specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Bronze Trolley Wire (A.S.T.M. Designation: B 9 - 32), 1933 Book of A.S.T.M. Standards, Part I, p. 757.

These specifications were prepared under the joint cooperation of the American Transit Engineering Association, the Association of American Railroads and the American Society for Testing Materials.

[2] Where wire is to be used for steam railway electrification, the corrosive action of locomotive gases should be given consideration.

[3] 1933 Book of A.S.T.M. Standards, Part I, p. 573.

[4] *Ibid.*, p. 568.

PROPERTIES AND TESTS

(*A*) *Round Wire*

Tensile Strength and Elongation

4. (*a*) Round wire shall be so drawn that its tensile strength and elongation shall be not less than the values shown in Table I. The elongation shall be determined as the permanent increase in length due to the breaking of the wire in tension measured between gage marks placed originally 10 in. apart upon the test specimen. The fracture shall be between the gage marks and not closer than 1 in. to either gage mark.

(*b*) Tests upon a specimen of round wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests shall not be made on specimens including brazes.

TABLE I.—VALUES FOR TENSILE STRENGTH AND ELONGATION OF ROUND TROLLEY WIRE.

Diameter, in.	Area, circular mils	Class *A* Bronze Wire		Class *B* Bronze Wire		Class *C* Bronze Wire	
		Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent
0.548	300 000	64 800	4.50	57 800	4.50	61 500	4.50
0.460	211 600	69 000	3.75	61 000	3.75	65 000	3.75
0.410	168 100	71 000	3.25	63 000	3.25	67 000	3.25
0.365	133 200	73 000	2.75	65 000	2.75	69 000	2.75
0.325	105 600	76 000	2.40	68 000	2.40	72 000	2.40

Twist Test

5. (*a*) For the purpose of determining and developing defects which may be prejudicial to the life of trolley wire, owing to its peculiar service as compared to that of wire for other purposes, round wire shall be subjected to the twist test described in Paragraph (*b*). Round wire shall not be considered satisfactory which does not stand, without breaking, at least the following number of twists:

DIAMETER, IN.	NUMBER OF TWISTS
0.548	20
0.460	23
0.410	25
0.365	27
0.325	30

(*b*) Three twist tests shall be made upon specimens 10 in. in length between the holders of the testing machine. The twisting machine shall be so constructed that there is a linear motion of the tail stock with respect to the head. The twist shall be applied not faster than 10 turns per min. All three specimens shall be twisted to destruction and shall not reveal under test any seams, pits, slivers, or surface imperfections of sufficient magnitude to indicate inherent defects or imperfections in the wire. At the time of fracture the wire shall be twisting with reasonable uniformity.

Resistivity

6. (*a*) Trolley wire shall not exceed in resistivity the following values:[a]

WIRE	RESISTIVITY AT 20 C.
Class *A*	2188 lb. per mile ohm
Class *B*	1346 lb. per mile ohm
Class *C*	1094 lb. per mile ohm

(*b*) Lower resistivities in wires meeting the physical qualifications may be obtained by the use of special alloys.

(*c*) Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20 C. (68 F.).

(*B*) *Grooved Wire*

Tensile Strength and Elongation

7. (*a*) Tensile strength and elongation of grooved wire shall be not less than the values shown in Table II. The tension and elongation tests for grooved wire shall be made in the same manner as those upon round wire as described in Section 4 (*a*).

TABLE II.—VALUES FOR TENSILE STRENGTH AND ELONGATION OF GROOVED TROLLEY WIRE.

Nominal Area, circular mils	Class *A* Bronze Wire		Class *B* Bronze Wire		Class *C* Bronze Wire	
	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent
350 000	62 500	4.00	56 200	4.00	59 500	4.00
300 000	64 800	4.00	57 800	4.00	61 500	4.00
211 600	69 000	3.25	61 000	3.25	65 000	3.25
168 100	71 000	2.75	63 000	2.75	67 000	2.75
133 200	73 000	2.25	65 000	2.25	69 000	2.25

(*b*) Tests upon a specimen of grooved wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests shall not be made on specimens including brazes.

Twist Test

8. For the purpose of determining and developing defects which may be prejudicial to the life of trolley wire, owing to its peculiar service as compared to that of wire for other purposes, grooved wire shall be subjected to the twist test described in Section 5 (*b*). Grooved wire shall not be considered satisfactory which does not stand at least three twists without breaking.

Resistivity

9. The requirements for resistivity of grooved wire shall be the same as those specified in Section 6 for round wire of the same nominal cross-sectional area.

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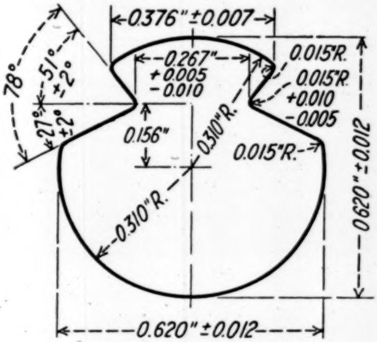
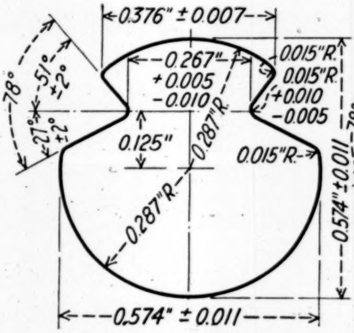
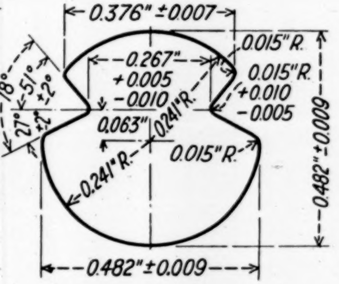
[a] These values represent classes of bronze wire formerly referred to as 40 per cent, 65 per cent, and 80 per cent conductivity wire, respectively.


0.376" ±0.007
0.267"
+0.005
-0.010
0.015"R.
0.015"R.
+0.010
-0.005
78°
51° ±2°
27° ±2°
0.156"
0.310" R.
0.015" R.
0.310" R.
0.620" ±0.012
0.620" ±0.012

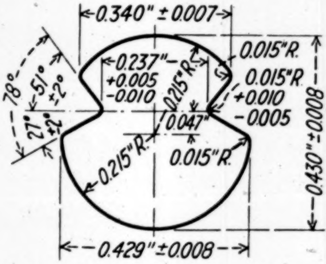
Grooved Wire
Nominal Cir. Mils, 350,000
Actual Area, 0.2758 sq. in.
Calculated Weight, 5612 lb. per mile


0.376" ± 0.007
0.267"
+0.005
-0.010
0.015"R.
0.015"R.
+0.010
-0.005
78°
51° ±2°
27° ±2°
0.125"
0.287" R.
0.015" R.
0.287" R.
0.574" ±0.011
0.574" ± 0.011

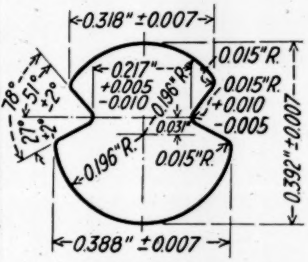
Grooved Wire
Nominal Cir. Mils, 300,000
Actual Area, 0.2355 sq. in.
Calculated Weight, 4792 lb.
per mile


0.376" ±0.007
0.267"
+0.005
-0.010
0.015" R.
0.015" R.
+0.010
-0.005
78°
51° ±2°
27° ±2°
0.063"
0.241" R.
0.015" R.
0.241" R.
0.482" ±0.009
0.482" ±0.009

Grooved Wire
Nominal Cir. Mils, 211,600
Actual Area, 0.1665 sq. in.
Calculated Weight, 3389 lb.
per mile


0.340" ± 0.007
0.237"
+0.005
-0.010
0.015" R.
0.015" R.
+0.010
-0.005
78°
51° ±2°
27° ±2°
0.047"
0.215" R.
0.015" R.
0.215" R.
0.430" ±0.008
0.429" ±0.008

Grooved Wire
Nominal Cir. Mils, 168,100
Actual Area, 0.1314 sq. in.
Calculated Weight, 2674 lb.
per mile


0.318" ±0.007
0.217"
+0.005
-0.010
0.015" R.
0.015" R.
+0.010
-0.005
78°
51° ±2°
27° ±2°
0.031"
0.196" R.
0.015" R.
0.196" R.
0.392" ±0.007
0.388" ±0.007

Grooved Wire
Nominal Cir. Mils, 133,200
Actual Area, 0.1083 sq. in.
Calculated Weight, 2205 lb.
per mile

FIG. 1.—Standard Sections Grooved Trolley Wire.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Density

10. For the purpose of calculating weights, cross-sections, etc., the density of the bronze[1] shall be taken as 8.89 g. per cu. cm. (0.321 lb. per cu. in.) at 20 C. (68 F.).

(A) *Round Wire*

Dimensions and Permissible Variations

11. (*a*) Size of round trolley wire shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals, that is, in mils.

(*b*) Wire shall be truly cylindrical in form. The diameter shall not vary more than 1 per cent over or under the diameter specified.

(B) *Grooved Wire*

Sections

12. Standard sections of grooved trolley wire shall be those known as the "American Standard Grooved Trolley Wire Sections" (the Standard Design of the American Transit Engineering Association), shown in Fig. 1.

Dimensions and Permissible Variations

13. (*a*) Size of grooved trolley wire shall be expressed as the nominal area of cross-section in circular mils, the standard sizes being as follows:

NOMINAL AREA, CIRCULAR MILS	ACTUAL AREA, CIRCULAR MILS	ACTUAL AREA, SQ. IN.	CALCULATED WEIGHT BASED ON ACTUAL AREA, LB. PER MILE
350 000	351 200	0.2758	5612
300 000	299 800	0.2355	4792
211 600	212 000	0.1665	3389
168 100	167 300	0.1314	2674
133 200	137 900	0.1083	2205

(*b*) The weight of grooved trolley wire shall not vary more than 4 per cent over or under the weights specified in Paragraph (*a*).

FINISH

Finish

14. (*a*) The wire shall be of uniform size, shape, and quality throughout, and shall be free from all scale, flaws, splits and scratches not consistent with the best commercial practice.

(*b*) Necessary brazes in trolley wire shall be as few as possible and shall be made in accordance with the best commercial practice.

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[1] Bronze trolley wire is an alloy as commonly produced of not less than 98 per cent copper with other metals. Determinations of the density of these alloys indicate, as might be expected, an average density practically the same as that found for copper.

PACKING

Packing and Shipping

15. (*a*) All wire shall be shipped on substantial reels, suitable for the weight of the wire handled, and shall be well protected from injury. The diameter of the reel drums shall be sufficiently large, not less than 30 in., to eliminate difficulty with waves or kinks when the wire is strung. If reels are to be lagged, it shall be so specified by the purchaser. The wire shall be reeled with turns tight together, in uniform layers, free from kinks and crosses. The relation between the vertical axis of grooved wire as finally strung and the axis of the reel shall be as specified by the purchaser and shall be approximately constant.

(*b*) The ends shall be securely fastened to the sides of the reel with no less than six staples. The staples shall be at least 2 in. in length and made from not less than 0.145-in. diameter wire. Care shall be exercised in stapling not to damage the surface of the exposed layer of wire. All reels shall have the arbor holes reinforced with steel plate at least $\frac{1}{2}$ in. in thickness, and unless otherwise specified, the arbor hole shall be a 4-in. square hole.

(*c*) Reels shall be marked legibly and indelibly with a serial number, size, kind, length and weight of wire, and such other information as is desired by the purchaser. The length or weight of wire to be wound upon reels shall be agreed upon by the manufacturer and purchaser in placing individual orders.

INSPECTION AND REJECTION

Inspection

16. All tests governing the acceptance or rejection of the wire, unless otherwise specified, shall be made at the place of manufacture with apparatus furnished by the manufacturer and in the presence of the purchaser, or his representative, who shall be furnished a copy of the tests. Every facility shall be given the purchaser, or his representative, to satisfy him as to the reliability of the results before the wire is delivered. If the purchaser waives inspection, and if he so elects at that time, he shall be furnished with a certified copy of tests made by the manufacturer.

Rejection

17. Any reel of wire which fails to meet the requirements of these specifications may be rejected. Failure of 30 per cent of the number of reels ready for inspection at one time shall be deemed sufficient cause for the rejection of the whole lot.

TENTATIVE SPECIFICATIONS
FOR
LEAD-COATED COPPER SHEETS[1]

A.S.T.M. Designation: B 101 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover lead-coated sheet copper for architectural uses. It is supplied in two types according to the method of manufacture, and in three classes according to the weight of coating.

Types

2. The lead coating shall be applied to the sheet copper as follows:

Type I.—By application of molten lead, or

Type II.—By electrodeposition.

Classes

3. (*a*) Except as may be specified under Paragraph (*c*), the following weights of lead coating shall apply for either Type I or Type II:

		Weight of Lead Coating, lb.[a]	
		Min.	Max.
Class A	Standard (for general utility)	12	15
Class B	Heavy	20	30
Class C	Extra Heavy	40	50

[a] In all classes the weight of coating, as designated, is the total weight of lead applied to two sides of 100 sq. ft. of copper sheet, approximately one half of the coating to be on each side of the sheet.

(*b*) Sheets specified to be coated on one side only shall have half the weights of lead coating prescribed in Paragraph (*a*).

(*c*) Other variations in coating or texture may be furnished under special written agreement between the purchaser and manufacturer.

MATERIAL

Copper

4. The copper sheet shall be made from copper having a purity of 99.900 per cent as determined by electrolytic assay, silver being counted as copper, conforming to the requirements of the Standard Specifications for

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[1] Under the standardization procedure of the Society these specifications are under the jurisdiction of the A.S.T.M. Committee B-2 on Non-Ferrous Metals and Alloys.

Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 4)[1] or the Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (A.S.T.M. Designation: B 5)[1] of the American Society for Testing Materials.

Lead

5. (*a*) The lead shall conform to the requirements of either Grades II or III of the Standard Specifications for Pig Lead (A.S.T.M. Designation: B 29) of the American Society for Testing Materials.[2]

(*b*) For Type I coating the lead shall be free from impurities other than those permitted in accordance with Paragraph (*a*), except that not more than 4 per cent of tin and a trace of phosphorus is permitted.

(*c*) For Type II coating the lead shall be free from impurities other than those permitted in accordance with Paragraph (*a*).

MANUFACTURE

Manufacture

6. The sheet copper used for lead coating may be finished by hot rolling, by hot and cold rolling and annealing, or by cold rolling. Unless otherwise specified, the lead coating shall be applied to the sheet before forming.

Temper

7. Lead-coated sheet copper shall be furnished as soft (roofing temper) or hard (cornice temper), the purchaser to specify whether soft material or hard material should be supplied.

PERMISSIBLE VARIATIONS IN WEIGHTS AND DIMENSIONS

Weights

8. (*a*) The minimum weights of lead-coated sheet copper shall conform to the following requirements:

NOMINAL WEIGHTS OF BARE COPPER SHEETS,[a] OZ. PER SQ. FT.	MINIMUM WEIGHTS OF LEAD-COATED SHEETS,[a] OZ. PER SQ. FT.		
	CLASS A	CLASS B	CLASS C
24	24.7	26.0	29.2
20	20.9	22.2	25.4
18	19.0	20.3	23.5
16	17.1	18.4	21.6
14	15.2	16.5	19.7

[a] The above weights are based on the minimum weights for copper sheets in case lots (95 per cent) and the minimum weights of lead coatings as given in Section 3.

Width

(*b*) The permissible variations in width for sheets shall be as follows:

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[1] 1933 Book of A.S.T.M. Standards, Part I, pp. 568 and 573.

[2] 1935 Supplement to Book of A.S.T.M. Standards, p. 26.

WIDTH, IN.	PERMISSIBLE VARIATIONS, IN.	
Up to and including 5	+0.025	−0
Over 5 to 14, inclusive	+0.050	−0
Over 14	+0.125	−0

Length

(*c*) Sheets ordered to exact lengths may have a variation of $+\frac{1}{8}$ in. in length.

WORKMANSHIP AND FINISH

Workmanship and Finish

9. Lead-coated copper sheet shall be uniform in quality and temper, clean, smooth, commercially straight or flat, and free from injurious defects.

PACKING AND MARKING

Packing

10. Lead-coated copper sheets shall be packed in accordance with good commercial practice in order to protect them from injury and loss during shipment.

Marking

11. Shipping containers shall be marked with the name and/or brand of the manufacturer, the size, number and nominal (copper) weight of the sheets and the weight of the coating, and the purchase order number. When required, individual sheets shall be marked with the name and/or brand of the manufacturer and the weight of the coating.

INSPECTION AND REJECTION

Inspection

12. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection

13. Individual sheets may be rejected by the inspector for obvious visual defects in the coating. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

METHODS OF SAMPLING AND TESTING

Chemical Analyses

14. The chemical requirements specified in Sections 4 and 5 shall be determined only on special request and the analyses shall be carried out in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Copper.*—Standard Methods of Battery Assay of Copper (A.S.T.M. Designation: B 34);[1]

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 580.

(*b*) *Lead.*—Standard Methods of Chemical Analysis of Pig Lead (A.S.T.M. Designation: B 35).[1]

Weight of Coating Test

15. When testing is specified, the determination of the weight of the lead coating shall be carried out in accordance with one of the three following methods. Unless otherwise specified, Method No. 1 shall be used:

(*a*) *Method No. 1.*—Ten sheets selected at random from each class of lead-coated sheets to be furnished shall be weighed before and after coating and the weight of the coating shall be calculated from the difference on the basis of the ordered size.

(*b*) *Method No. 2.*—One sheet shall be selected at random from each class of lead-coated sheets furnished. Four representative samples $2\frac{1}{4}$ by $2\frac{1}{4}$ in. shall be cut from each sheet, uniformly spaced along a diagonal, the end samples being taken not less than 1 in. from the edge. The four samples of each class of sheet so obtained shall be completely dissolved. The copper shall be determined by electrolytic assay. The weight of the lead coating shall be taken as the difference between the total weight of the samples and the weight of copper found. If necessary, a separate assay may be made for the tin.

(*c*) *Method No. 3.*—One sheet shall be selected at random from each class of lead-coated sheets furnished. Four representative samples $2\frac{1}{4}$ by $2\frac{1}{4}$ in. shall be cut from each sheet, uniformly spaced along a diagonal, the end samples being taken not less than 1 in. from the edge. After removing the burrs, each sample shall be cleaned and finally rinsed with alcohol and ether. The weight of the lead-coated sheet and the weight of the coating shall be obtained from measurements carefully taken of the specific gravity or density of these samples as determined by the usual method of weighing in air and water. Calculations may be made from the following formulas:

$$\text{Weight of lead coating, lb. per 100 sq. ft.} = \left(29.1 - \frac{259}{D}\right) W$$

$$\text{Weight of bare copper sheet, oz. per sq. ft.} = \left(\frac{41.5}{D} - 3.66\right) W$$

where W = the weight of a sample in air in grams

D_t = the density of water at room temperature

D = the density of the sample $= \dfrac{W \times D_t}{W - M}$

M = the weight of the sample in water in grams

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 791.

TENTATIVE SPECIFICATIONS
FOR
COPPER-SILICON ALLOY WIRE FOR GENERAL PURPOSES[1]

A.S.T.M. Designation: B 99 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935; REVISED, 1935.[2]

Scope

1. These specifications cover round copper-silicon alloy wire for general structural purposes except for electrical transmission cable.

MANUFACTURE

Manufacture

2. The material shall be copper-silicon alloy of such quality and purity that when finished, it shall have the properties and characteristics herein specified.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition

3. The material shall conform to the following requirements as to chemical composition:

Silicon, per cent	1.00 to 5.00
Manganese, max., per cent	1.50
Zinc, max., per cent	5.00
Iron, max., per cent	2.50
Tin, max., per cent	2.00
Aluminum, max., per cent	2.00
Copper, per cent	remainder
Sum of above elements, min., per cent	99.50

Chemical Analysis

4. (*a*) Chemical analysis shall be made on each lot of 5000 lb. or fraction thereof.

(*b*) The sample for chemical analysis shall consist of clean drillings, millings or clippings taken from representative specimens of wire selected for purpose of tests. Equal quantities from each of the specimens sampled shall be thoroughly mixed. Samples so prepared shall be divided into three equal parts, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

By adoption of these specifications, the American Society for Testing Materials does not undertake to insure anyone utilizing such specifications against liability for infringement of any patent or assume any such liability, and such adoption does not constitute a recommendation of any patented or proprietary application that may be involved.

[2] Revision accepted by Committee E-10 on Standards, August 22, 1935.

PHYSICAL PROPERTIES AND TESTS

Physical Properties

5. (*a*) The wire shall conform to the physical properties shown in the following table:

TEMPER	GRAIN SIZE, MM.	TENSILE STRENGTH, LB. PER SQ. IN.	BEND
Annealed	0.040 max.[a]	56 000 to 68 000	......
Quarter Hard[b]	......	75 000 to 88 000	......
Half Hard[b]	......	90 000 min.	......
Hard[b]	......	115 000 min.	180 deg. flat
Extra Hard[b] (up to $\frac{3}{8}$ in., incl., only)	......	125 000 min.	around itself
Spring[b] (up to $\frac{1}{4}$ in., incl., only)	......	135 000 min.	around itself

[a] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

[b] The terms "Quarter Hard," "Half Hard," etc., as used here do not necessarily signify reductions of 1, 2, 4, 6 and 8 B. & S. numbers hard as would be the case in coppers or brasses. This is because these specifications permit of a fairly wide range of composition so that the physical properties listed for any given nominal temper might be met by a certain percentage reduction with one alloy and a somewhat different reduction with another alloy, both of which alloys would be within the range of composition permitted.

(*b*) Tests upon a specimen of wire containing a braze or weld shall show at least 95 per cent of the tensile strength of the unbrazed wire. Bend tests shall not be made upon specimens including brazes or welds.

Grain Size Determination

6. In determining grain size, reference should be made to the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (A.S.T.M. Designation: E 2) of the American Society for Testing Materials.[1]

Number of Tests

7. (*a*) Two tension test specimens and one specimen for the bend test or grain size determination, where required, shall be selected from each lot of 10,000 lb. or fraction thereof. Tension and bend tests shall be made on full sections of the wire.

(*b*) If upon testing a specimen from any coil of wire the results are found to be below the values specified in Section 5, tests upon two additional specimens shall be made and the average of the three tests shall determine the acceptance or rejection of the coil.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions and Permissible Variations

8. (*a*) The size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 900.

(*b*) Wire shall be accurate in diameter; permissible variations from the nominal diameter shall be within the following requirements:

Wire Diameter	Permissible Variation	
	Over	Under
Under 0.010 in.	0.001 in.	0.001 in.
0.010 in. and over	3 per cent	1 per cent

(*c*) Each coil shall be gaged at three places, one near each end and one approximately at the middle; the coil may be rejected if the measurements at two points being within the accepted limits, the measurement at the third point is not within the accepted limits.

Workmanship and Finish

Workmanship and Finish

9. (*a*) The wire shall be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in wire shall be made in accordance with the best commercial practice.

Packing

Packing

10. (*a*) Package sizes for wire shall be agreed upon by the manufacturer and purchaser in the placing of individual orders.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

Inspection and Rejection

Inspection

11. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection

12. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS
FOR
LEAD AND TIN-BASE ALLOY DIE CASTINGS[1]

A.S.T.M. Designation: B 102 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover die castings made by pressure casting from the following alloys: tin-base, lead-base and intermediate. Five typical alloys are specified and are designated as Grades Nos. 1 to 5, in order of decreasing tin content.

Chemical Composition

2. The alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 3:

Alloy Grade	Tin, per cent	Antimony, per cent	Lead, per cent	Copper, per cent	Iron, max., per cent	Arsenic, max., per cent	Zinc, max., per cent	Aluminum, max., per cent
No. 1[b]............	91	4.5	0.35[a]	4.5	0.08	0.08	0.01	0.01
No. 2............	82	13	0.35[a]	5	0.08	0.08	0.01	0.01
No. 3[b]............	65	15	18	2	0.08	0.15	0.01	0.01
No. 4[b]............	5	15	80	0.50[a]	....	0.15	0.01	0.01
No. 5[b]............	....	10	90	0.50[a]	....	0.15	0.01	0.01

[a] Maximum.

[b] These alloy grades are similar to Grades Nos. 1, 5, 8 and 12, respectively, of the Standard Specifications for White Metal Bearing Alloys (Known Commercially as "Babbitt Metal") (A.S.T.M. Designation: B 23) of the American Society for Testing Materials, see 1933 Book of A.S.T.M. Standards, Part I, p. 841.

Permissible Variations

3. The following permissible variations in the percentages of the desired elements specified in Section 2 will be allowed, but shall not apply to the maximum percentages of impurities specified:

PERCENTAGE OF ELEMENT SPECIFIED	PERMISSIBLE VARIATIONS OVER OR UNDER THE SPECIFIED VALUE, UNITS OF PER CENT
Not over 2 per cent....................................	0.25
Over 2 to 5 per cent, incl....................................	0.50
Over 5 to 10 per cent, incl....................................	0.75
Over 10 per cent....................................	1.00

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee B-6 on Die-Cast Metals and Alloys.

TENTATIVE SPECIFICATIONS
FOR
WROUGHT-IRON PLATES[1]

A.S.T.M. Designation: A 42 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.

Scope

1. These specifications cover wrought-iron[2] plates for general fabrication purposes, including bending and flanging, in thicknesses $\frac{3}{16}$ in. and over.

Manufacture

2. (*a*) All plates shall be rolled from blooms, piles or slabs which are entirely free from any admixture of iron scrap (Note) or steel.

(*b*) Piles for plates shall be made from wrought iron.[2] The constituent bars shall be the full length of the pile.

NOTE.—The term iron scrap applies only to foreign or bought scrap and does not include local mill products which are free from foreign or bought scrap. Any local mill products used shall be the equal or of a higher grade than the material specified.

Chemical Composition

3. The iron shall conform to the following requirement as to chemical composition:

Manganese, max., per cent.................................. 0.05

Tension Tests

4. (*a*) The plates shall conform to minimum requirements as to tensile properties, calculated from the following formulas:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee A-2 on Wrought Iron.

These tentative specifications are in effect a tentative revision of, and will supersede when adopted as standard, the present Standard Specifications for Wrought-Iron Plates (A.S.T.M. Designation: A 42 - 30), 1933 Book of A.S.T.M. Standards, Part I, p. 459.

[2] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Tensile strength, lb. per sq. in. = 51,000 − (1500 × transverse ductility of plate (expressed as percentage elongation in 8 in.))

Longitudinal elongation in 8 in., per cent = 16 − transverse ductility (expressed as percentage elongation in 8 in.)

Yield point, lb. per sq. in 27,000

(*b*) On the basis of the above formulas, the purchaser of the plate shall indicate the transverse ductility desired in conformity with his fabrication requirements. The usual longitudinal strength and ductility are directly related thereto, and are scaled downward in ratio to the increase in transverse properties desired.

(*c*) Representative requirements in accordance with the formulas are as follows:

TRANSVERSE DUCTILITY (ELONGATION IN 8 IN.), PER CENT	MINIMUM LONGITUDINAL PROPERTIES	
	TENSILE STRENGTH,[a] MIN., LB. PER SQ. IN.	ELONGATION[b] IN 8 IN., MIN., PER CENT
2	51,000 − (1500 × 2) = 48 000[c]	(16 − 2) = 14[c]
3	46 500	13
4	45 000	12
5	43 500	11
6	42 000	10
7	40 500	9
8	39 000	8

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[a] See Section 5 (*a*).
[b] See Section 5 (*b*).
[c] Test requirements for the usual full longitudinal rolling of the plate.

(*d*) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Modifications in Elongation

5. (*a*) For plates over $\frac{3}{4}$ in. in thickness, a reduction of 1000 lb. per sq. in. from the indicated tensile strength will be allowed for each increase of $\frac{1}{8}$ in. in thickness over $\frac{3}{4}$ in., with a proportional reduction for fractional parts of $\frac{1}{8}$ in.; but in no case less than 39,000 lb. per sq. in.

(*b*) For plates under $\frac{7}{16}$ in. in thickness, a deduction of 1 per cent from the percentages of elongation specified in Section 4 shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{7}{16}$ in.

Bend Tests

6. (*a*) *Cold-bend Tests.*—The test specimen shall stand being bent cold through 90 deg., without fracture on the outside of the bent portion, around a pin the diameter of which is:

$$d = \frac{40 \times \text{thickness of plate}}{\text{specified longitudinal elongation in 8 in., per cent}}$$

Furnace Control

5. Rheostats or other means shall be provided that will enable the power input to the test furnace to be controlled to close limits. It should be possible to alter the power to the furnace by increments of less than 0.5 per cent and the voltage of the power circuit should not be subject to sudden fluctuations.

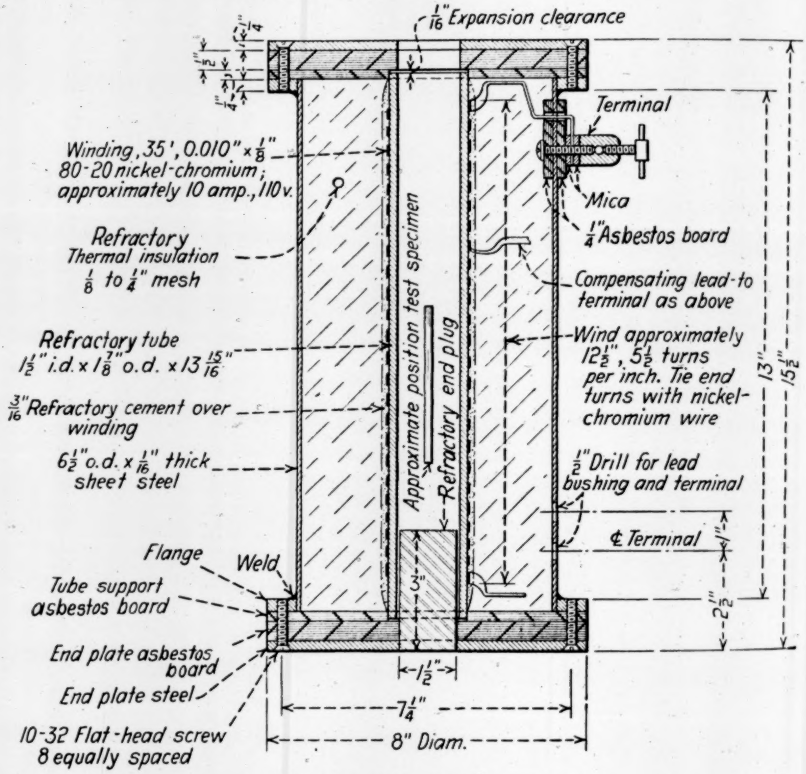
1/16" Expansion clearance
1/4"
1/2"
1/4"
Terminal
Winding, 35', 0.010" × 1/8" 80-20 nickel-chromium; approximately 10 amp., 110 v.
Mica
1/4" Asbestos board
Refractory Thermal insulation 1/8 to 1/4" mesh
Approximate position test specimen
Refractory end plug
Compensating lead-to terminal as above
Refractory tube 1 1/2" i.d. × 1 7/8" o.d. × 13 15/16"
Wind approximately 12 1/2", 5 1/2 turns per inch. Tie end turns with nickel-chromium wire
3/16" Refractory cement over winding
13"
15 1/2"
6 1/2" o.d. × 1/16" thick sheet steel
1/2" Drill for lead bushing and terminal
℄ Terminal
1"
Flange
Weld
Tube support asbestos board
3"
2 1/2"
End plate asbestos board
End plate steel
1 1/2"
7 1/4"
10-32 Flat-head screw 8 equally spaced
8" Diam.

FIG. 1.—Expansion Furnace.

Furnace Power Measuring Instruments

6. A wattmeter or other means shall be provided that will enable the power input to the furnace to be measured with an accuracy of 5 per cent and which is sufficiently sensitive to clearly indicate power changes of 1 per cent.

Temperature Measuring Instruments

7. (*a*) *Thermocouples and Potentiometer.*—During the test the temperatures near the ends and middle of the specimen shall be determined by means of thermocouples with an accuracy of ±5 C. The sensitivity of the potentiometer or the device used for measuring the

temperature shall be such that the temperature differences or temperature changes of 2 C. or more are clearly indicated.

(*b*) Nickel chromium - nickel aluminum (sold as Chromel-Alumel or Nichrome T-1—Nichrome T-2), nickel chromium - constantan (sold as Chromel-constantan or Nichrome T-1—constantan), iron-constantan, or platinum-rhodium thermocouples, in conjunction with a potentiometer, may be used. If the potentiometer is of the industrial type, it shall be calibrated and the scale corrections thus determined shall be applied. The cold junctions shall either be maintained at 0 C. by means of an ice bath or else the temperature determined by means of a liquid-in-glass thermometer placed very near them.

(*c*) Iron-constantan or nickel chromium - constantan (sold as Chromel-constantan or Nichrome T-1—constantan) couples shall not be used for runs above 500 C. and nickel chromium - nickel aluminum (sold as Chromel-Alumel or Nichrome T-1—Nichrome T-2) couples for runs above 800 C. If base-metal couples are used they shall not be smaller than B. & S. gage No. 28 and shall be taken from coils of wire from which at least two other couples selected from different parts of the coil have been calibrated. Each sample shall be used for not more than two cycles of heating and cooling.

(*d*) A platinum-rhodium couple shall be used above 800 C., protected by a porcelain tube to within a few millimeters of the hot junction. The end of the couple shall be sealed through the end of the protection tube by pyrex glass (or a small amount of kaolin and water-glass cement) to prevent contamination of the couple, with the exception of a small length of 2 or 3 mm. near the hot junction which is attached to the specimen. After each cycle of heating and cooling, the seal shall be examined and if it is not in good condition, or if the projecting ends of the wires are brittle, this part of the wires shall be cut off and enough wire drawn through the seal to form a new junction.

TEST SPECIMEN

Shape and Size of Specimen

8. The test specimen shall be a rod 4 in. ±0.01 in. in length with the ends machined flat and parallel to within 0.0001 in. The measurement of the length shall be made after the thermocouples have been attached, in order to avoid the chance of error in the measurement due to any change caused by the method of attaching the thermocouples. The diameter shall be not less than $\frac{1}{4}$ nor more than $\frac{7}{16}$ in., and shall not vary throughout the length of a specimen more than 0.01 in. The surface shall be free from scratches or other surface irregularities that can interfere with freedom of motion of the specimen in the dilatometer.

Other Tests

9. Where desired, the purchaser may, at his own expense, subject the material to chemical, microscopic, or other tests to determine its quality in conformity with the intent of these specifications.

Variations in Weight and Thickness

10. The weight or thickness of plates shall be covered by the following permissible variations. One cubic inch of wrought iron is assumed to weigh 0.2776 lb.

(*a*) *Plates, When Ordered to Weight per Square Foot.*—The weight of each lot[1] of plates in each shipment shall not vary from the weight ordered more than the amounts given in Table I.

(*b*) *Plates, When Ordered to Thickness.*—The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight in each lot[1] of plates in each shipment shall not exceed the amounts given in Table II.

Finish

11. The plates shall be straight, smooth and free from cinder spots and holes, injurious flaws, buckles, blisters, seams and laminations.

Marking

12. The plates shall be stamped or otherwise marked as designated by the purchaser.

Inspection

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the plates ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the plates are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of plates at his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

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[1] The term "lot" as applied to Table I means all the plates of each group width and group weight. As applied to Table II, it means all the plates of each group width and group thickness.

Rejection

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

15. Samples tested in accordance with Section 13 (*b*), which represent rejected plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

(*b*) Apply power to the furnace and adjust from time to time to give the desired heating or cooling rate.

(*c*) Take temperature and dilatometer readings alternately and record together with the times of each of the readings.

(*d*) The final measurement of the specimen shall be performed as specified for the standard method in accordance with Section 11.

(*e*) From these readings plot time-temperature curves for each of the thermocouples and also a time-dilation curve, all referred to a common time zero. By means of these curves the temperatures and the corresponding dilatometer readings can be closely approximated for each of an arbitrarily chosen series of times. These coordinated temperature and dilatation values enable the construction of temperature-dilatation curves of sufficient accuracy for many purposes and are acceptable if the procedure has been previously agreed upon.

REPORT

13. *Identification of Specimen.*—The report shall include the following information concerning the test specimen:

(*a*) Date of test.

(*b*) Designation of material. The chemical analysis is valuable in identifying the material.

(*c*) History of material, especially that relating to thermal or mechanical treatment, whether cast or wrought, etc.

(*d*) Notes as to physical appearance of specimen, straightness, defects, or other observations that may have a bearing on the interpretation of the test data.

(*e*) Remarks as to final physical appearance of sample and conditions of oxidation, warping, cracks, etc., and any other data which may have a bearing on the interpretation of the test data.

14. *Data for Standard Method.*—When the standard method is used, the report shall include the following information:

(*a*) Initial length and diameter of specimen and temperature at which they were measured.

(*b*) Test data at elevated temperatures as follows:

(*1*) Observed temperatures.

(*2*) Corresponding dilatometer readings.

(*3*) Corresponding observed length changes referred to the original length of the specimen as datum.

(*4*) Corrections to be applied to (*3*) to compensate for the dilation of that portion of the dilatometer tube opposite the test specimen.

15. *Data for Rapid Method.*—When the rapid method is used, the report shall include the following information:

(*a*) Test data at room temperature as follows:

- (*1*) Length of specimen;
- (*2*) Diameter of specimen.

(*b*) Test data at elevated temperatures, in the form of tables or graphs, as follows:

- (*1*) Observed temperatures;
- (*2*) Times of observation;
- (*3*) Corresponding dilatometer readings;
- (*4*) Times of dilatometer observations;
- (*5*) Time-temperature and time-expansion curves;
- (*6*) Table showing:
  - (*a*) Arbitrarily chosen temperatures in test range;
  - (*b*) Dilatometer readings corresponding in time to temperatures of (*a*);
  - (*c*) Length changes derived from (*b*) referred to original length of specimen as datum;
  - (*d*) Corrections for expansivity of dilatometer as described under Section 16.

physical test requirements of Section 4 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different bar will be allowed.

Micrographic Examination

8. In case of doubt as to the presence of steel, the purchaser may, at his own expense, make micrographic examination to assist in determining whether the material conforms to the requirements of Section 1.

Permissible Variations

9. The diameter of rivet bars shall not vary from that specified by more than the amount given in the following table:

DIAMETER, IN.	PERMISSIBLE VARIATIONS IN DIAMETER, IN.	OUT OF ROUND, IN.
Up to ½, inclusive	±0.007	0.010
Over ½ to 1, inclusive	±0.010	0.013
Over 1 to 1¼, inclusive	±0.012	0.016
Over 1¼ to 1½, inclusive	±0.015	0.021
Over 1½ to 2, inclusive	±0.022	0.023

Finish

10. The bars shall be smoothly rolled and shall be free from slivers, depressions, crop ends and seams, and shall show no evidence of being burnt.

INSPECTION AND REJECTION

Inspection

11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

12. (*a*) All bars of one size in any one lot will be rejected if the test specimens representing that size and lot do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 11 (*b*) shall be reported within five working days from the receipt of samples.

Rehearing

13. Samples tested in accordance with Section 11 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Finished Rivets

Material

14. The material used in the manufacture of the rivets shall conform to the requirements for rolled bars as specified in Sections 1 to 13, inclusive.

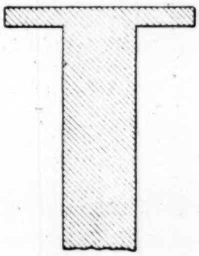

FIG. 1.—Flattening Test.

PHYSICAL PROPERTIES AND TESTS

Flattening Test

15. The rivet head shall stand being flattened, while hot, to a diameter two times the diameter of the shank, as shown in Fig. 1, without cracking at the edges.

Etch Test

16. The rivet shall be split longitudinally through head and shank. After grinding or polishing and etching in acid,[1] the section shall show freedom of folds at base of head, and the fiber lines shall show symmetrical displacement. (See Fig. 2).

Number of Tests

17. Three flattening and three etch tests shall be made from

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[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp gr. 1.42) and 75 per cent water, is recommended for the etch test.

4 in. above the centering screws. The grooves of the V blocks engage the fiduciary projections at the top of the dilatometer tube. The axis of one of the V grooves is parallel to the dilatometer axis and provides transverse and rotational constraint. The other V groove lies in a plane perpendicular to the dilatometer axis and provides axial constraint as well as lateral constraint in directions at right angles to that provided by the other V block. A thin metal strap with threaded terminals is provided to hold the dilatometer in contact with the four guide elements. This set-up locates the dilatometer in a fixed and reproducible manner with respect to a definite plane passing through the transverse V block and so causes all axial changes to be referred to this guide block. The length of the transmission rod is so adjusted that its upper end lies in or near the plane perpendicular to the dilatometer axis and passing through the apex of the transverse V groove. Thus the expansion of the carrier member between this plane and the parallel plane passing through the point of attachment of the dial gage is compensated by the nearly equal and oppositely directed expansion of the gage between its point of attachment and the lower end of the gage contact pin.

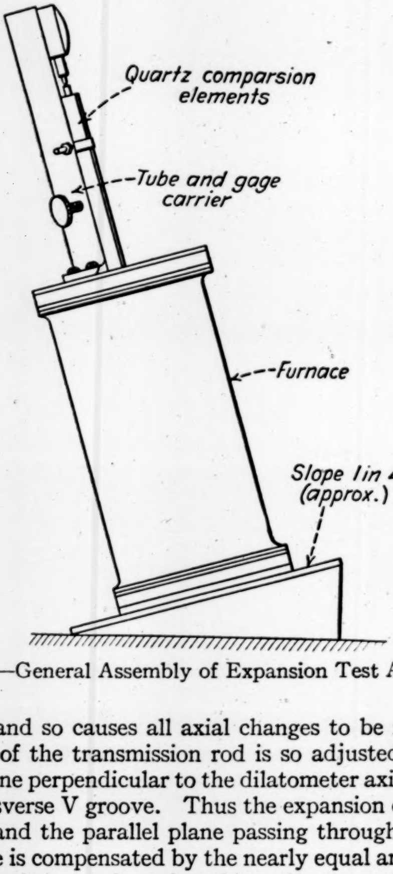

FIG. A3.—General Assembly of Expansion Test Apparatus.

Figure A3 shows an assembly of the furnace and dilatometer parts mounted on an inclined base so that the test specimen is held by gravity against the guiding indentations in the dilatometer tube while at the same time being free of any appreciable bending stresses that would tend to cause plastic flexure at the higher temperatures.

Attachment of the dilatometer carrier to the upper head of the furnace gives a very satisfactory assembly, but requires that this end of the furnace be provided with good thermal insulation and that heat flow to and along the carrier be obstructed as much as possible as by placing insulation under the attachment lugs and cutting holes or transverse slots in the webs of the carrier to reduce the effective cross-section offered to the flow of heat.

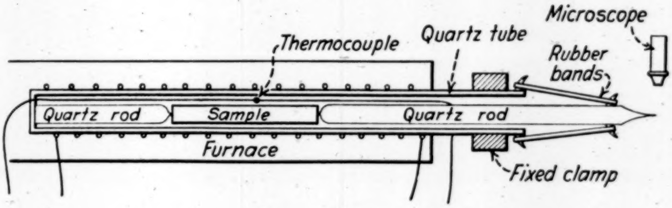

Fig. A4.—Type of Assembly for Use With Microscope.

Quartz Tube, 11 in.
Specimen, 2 in. long by 0.120 in. Diameter, Planed Ends.
α of Quartz, 0.00000054.
Quartz Rods and Tube Compensate Each Other.
Correction Made for 2-in. Quartz Tube at Specimen.

In Fig. A4 is shown a type of assembly that is intended for use with a microscope as a means of measuring dilatation. This representation is diagrammatic only and if this scheme is followed care shall be taken to provide such details of support for the cooperating parts as will ensure the required sensitivity and accuracy.

side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

(*c*) The bend test shall be made on a specimen from one sheet in each lot of 250 sheets or fraction thereof of each gage.

(*d*) If any test fails to meet the requirements, a retest shall be made from two other sheets of the same lot, both of which shall meet the requirements.

Weight

5. (*a*) The weight per square foot shall conform to the following requirements:

GAGE	WEIGHT PER SQUARE FOOT, LB.	APPROXIMATE THICKNESS, FRACTIONS OF AN INCH	APPROXIMATE THICKNESS, DECIMALS OF AN INCH
No. 8	6.875	$\frac{11}{64}$	0.172
No. 9	6.25	$\frac{5}{32}$	0.156
No. 10	5.625	$\frac{9}{64}$	0.141
No. 11	5.00	$\frac{1}{8}$	0.125
No. 12	4.375	$\frac{7}{64}$	0.109
No. 13	3.75	$\frac{3}{32}$	0.094
No. 14	3.125	$\frac{5}{64}$	0.078
No. 15	2.8125	$\frac{9}{128}$	0.070
No. 16	2.50	$\frac{1}{16}$	0.063
No. 17	2.25	$\frac{9}{160}$	0.056
No. 18	2.00	$\frac{1}{20}$	0.050
No. 19	1.75	$\frac{7}{160}$	0.044
No. 20	1.50	$\frac{3}{80}$	0.038
No. 21	1.375	$\frac{11}{320}$	0.034
No. 22	1.25	$\frac{1}{32}$	0.031
No. 23	1.125	$\frac{9}{320}$	0.028
No. 24	1.00	$\frac{1}{40}$	0.025
No. 25	0.875	$\frac{7}{320}$	0.022
No. 26	0.75	$\frac{3}{160}$	0.019
No. 27	0.6875	$\frac{11}{640}$	0.017
No. 28	0.625	$\frac{1}{64}$	0.016

(*b*) A permissible variation in tonnage weight of $2\frac{1}{2}$ per cent over or under for gages Nos. 17 to 28, inclusive, and 5 per cent over or under for gages No. 16 and heavier shall be allowed.

Dimensions

6. Sheets shall conform to the dimensions specified, within the permissible variations prescribed in the following Paragraphs (*a*) to (*c*):

(*a*) The width shall not be less than specified, but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall not be less than that specified, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof over 96 in., the permissible variation may be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "re-squared." Re-squared sheets shall not be less than the ordered width and length and shall not be more than $\frac{1}{16}$ in. over the ordered width and length, except for sheets over 48 in. in width or over 120 in. in length, in which case the permissible variation over the ordered size shall be $\frac{1}{8}$ in.

Marking

7. The top sheet of each bundle or the top sheet of a number of sheets when shipped loose, shall show legibly the name and brand of the manufacturer, gage and size, unless otherwise ordered.

Inspection

8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer of the material ordered shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

9. (*a*) Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected, and the manufacturer shall be notified.

(*b*) Samples tested in accordance with these specifications which represent rejected material shall be preserved for two weeks from the date of the test report.

ately filtered, and the separated silica washed thoroughly with hot water and reserved. The filtrate shall again be evaporated to dryness, the residue being baked in an oven 1 hr. at a temperature of 105 to 110 C. The residue shall then be taken up with 10 to 15 ml. of dilute HCl (1:1) and heated on the hot plate. The solution shall be diluted with an equal volume of hot water and the small amount of silica it contains caught and washed on another filter paper. The filtrate and washings shall be reserved. This paper and the reserved paper containing the residues shall be transferred to a weighed platinum crucible, dried, ignited first over a bunsen burner until the carbon of the filter paper is completely consumed without flaming and finally over a burner or in an electric oven at 1100 to 1200 C. until the weight remains constant.

(*b*) The silica thus obtained will contain small amounts of impurities. It shall then be treated in the crucible with a few drops of water, about 10 ml. of HF and one drop of H_2SO_4 and evaporated to dryness over a low flame. The small residue shall be finally heated at 1050 to 1100 C. for a minute or two, cooled, and weighed. The difference between this weight and the weight previously obtained represents the amount of silica. Washing of the silica precipitates can be made more effective by using a hot solution of dilute HCl (1:99), and then completing the washing with hot water. The weighed residue remaining after volatilization of the silica shall be considered as combined aluminum and ferric oxides and added to the result obtained in the determination of these oxides.

FERRIC OXIDE AND ALUMINA

Method

5. The reserved filtrate (Note), which should have a volume of about 250 ml., is treated with HCl, if necessary, to insure a total of 10 to 15 ml. of the acid, a few drops of methyl red indicator and then heated to boiling. It shall then be treated with NH_4OH, drop by drop, until one drop changes the color of the solution to a distinct yellow. The solution containing the precipitated iron and aluminum hydrates shall be brought to boiling, boiled for 1 or 2 min., and then filtered. The precipitate is washed once by decantation and slightly on the filter with a hot 2 per cent solution of ammonium nitrate. Setting aside the filtrate, the precipitate and filter paper shall be transferred to the same beaker in which the first precipitation was effected. The iron and aluminum hydrates shall then be dissolved in hot diluted HCl (1:3), the solution made up to about 100 ml., and the hydrates reprecipitated as in the first case. The solution shall then be filtered and the precipitate washed with two 10-ml. portions of a hot 2 per cent solution of ammonium nitrate. The filtrate and washings shall be combined with that set aside, and the precipitate placed in a weighed

platinum crucible, slowly heated by a bunsen or Meker burner until the papers are charred, and finally ignited to constant weight at 1050 to 1100 C. with care to prevent reduction, and weighed as $Al_2O_3 + Fe_2O_3$.

NOTE.—If a platinum evaporating dish has been used for the dehydration of silica, iron may have been partially reduced. At this stage, add about 3 ml. of saturated aqueous solution of bromine to the filtrate and boil the filtrate to eliminate the excess bromine before adding methyl red indicator.

FERRIC OXIDE

NOTE.—This determination is not affected by any titania or vanadium oxide that may be in the cement. It is, therefore, understood that these are counted as Al_2O_3 in this method. If the precipitations of aluminum and iron are made as directed, little if any manganese will be caught in the precipitate.

Solutions Required

6. The following solutions will be required:

(a) *Stannous Chloride.*—Dissolve 5 g. of the crystallized salt in four times its weight of a mixture of three parts of water and one of HCl (sp. gr. 1.19). Add scraps of iron-free granulated tin and boil until the solution is clear. Keep the solution in a closed dropping bottle containing metallic tin.

(b) *Phosphoric Acid Mixture.*—Add slowly and with stirring 150 ml. of orthophosphoric acid (sp. gr. 1.71), and 150 ml. of sulfuric acid (sp. gr. 1.84), to 500 ml. of water and then dilute to 1000 ml. with water and mix.

(c) *Diphenylamine Indicator.*—Dissolve 1 g. of diphenylamine in 100 ml. of sulfuric acid (sp. gr. 1.84).

(d) *Standard Potassium Dichromate Solution.*—Dissolve 2.457 g. of potassium dichromate in distilled water and dilute to 1 liter. Standardize against standard iron wire of known iron content in the same manner as directed for the ferric oxide determination in cement (Section 7), using a weight of iron wire which will yield a titration approximately equal to that required by the cement sample in question.

Method

7. To a 1-g. sample of cement shall be added 20 ml. of cold water and 10 ml. of HCl (sp. gr. 1.19). The solution shall be heated and the material ground with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. The solution shall be diluted to 50 ml. and heated to boiling. The solution shall then be treated with 5 ml. of HCl (sp. gr. 1.19) and then with a solution of stannous chloride, added drop by drop while stirring, until the solution is decolorized, when one drop more shall be added. The solution shall be cooled to room temperature, the inside of the vessel shall then be rinsed with water and 10 ml. of a cool

acid method, as described in Sections 5 to 9 of the Standard Methods of Determining Weight and Uniformity of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles (A.S.T.M. Designation: A 90) of the American Society for Testing Materials.[1] The weight of coating, in ounces per square foot, is numerically equal to that determined in grams from a sample $2\frac{1}{4}$ in. square.

Bend Tests

6. (*a*) *Base Metal Tests.*—Any part of the test specimen specified in Section 7 shall stand being bent cold without fracture of the base metal as follows: Where the line (axis) of the bend is parallel to the length of the sheet, 180 deg. over seven thicknesses of the material; and where the line (axis) of the bend is parallel to the width of the sheet, 180 deg. over three thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend tests.

(*b*) *Coating Tests.*—Sheets of Classes *A* and *B* of the following gages shall stand corrugating and also subsequent curving, as given below, without flaking of the coating. The corrugation for these tests shall not be less than $2\frac{2}{3}$ in. in width and not more than $\frac{1}{2}$ in. in depth.

GAGE	DIAMETER OF CIRCLE
No. 12	30 in.
No. 14	18 in.
No. 16	12 in.

For sheets of Class *C* of No. 16 gage and lighter, any part of the test specimen specified in Section 7 shall stand being bent with the line (axis) of the bend parallel to the width of the sheet through 180 deg. over three thicknesses of the material without flaking of the coating.

Test Specimens

7. For the triple and minimum spot tests, three specimens exactly $2\frac{1}{4}$ in. square shall be cut from each test sheet, one being cut from the center and the others from diagonally opposite corners, but at least 4 in. from the end and 2 in. from the side. The bend test specimens shall be from 3 to 4 in. in width and shall be cut from the test sheet at least 4 in. from the end and 2 in. from the side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

Number of Tests

8. (*a*) Weight tests shall be made of not less than 1 per cent of the sheets of each gage and ordered coating, or at approximately hourly periods. If an inspector representing the purchaser witnesses and accepts weight

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 317.

tests, the triple and minimum spot tests shall not be made. If a certificate of weight tests be accepted, the triple and minimum spot tests shall not be made.

(*b*) The bend and spot tests, if required, shall be made from one sheet in each lot of 250 sheets or fraction thereof, of each gage and ordered coating.

(*c*) If any test fails to meet the requirements of these specifications, a retest shall be made from two other sheets in the same lot, both of which shall meet the requirements.

Dimensions and Permissible Variations

9. The sheets shall conform to the dimensions specified within the permissible variations prescribed in the following Paragraphs (*a*) to (*c*):

(*a*) The width shall not be less than that specified but may be $\frac{1}{4}$ in. over for sheets 48 in. or less in width, and $\frac{3}{8}$ in. over for sheets over 48 in. in width.

(*b*) The length shall not be less than that ordered, but for sheets 96 in. or less in length it may be $\frac{3}{4}$ in. greater. For each 24 in. or fraction thereof above 96 in., the permissible variation shall be increased $\frac{1}{4}$ in. over $\frac{3}{4}$ in.

(*c*) When sheets are required accurate to size, they shall be ordered "re-squared." Re-squared sheets shall not be less than the ordered width and length and shall not be more than $\frac{1}{16}$ in. over the ordered width and length, except in the case of sheets over 48 in. in width or over 120 in. in length, in which case the permissible variation from the ordered size shall be $\frac{1}{8}$ in. Should the sheets be re-squared before galvanizing, double the foregoing tolerances are permissible.

Weight

10. The gage of galvanized sheets shall be determined by weight only. The weight per square foot of galvanized sheet shall conform to the following requirements within the permissible variations prescribed in Table III:

GALVANIZED SHEET GAGE	WEIGHT OF GALVANIZED SHEETS, ALL CLASSES	
	OZ. PER SQ. FT.	LB. PER SQ. FT.
No. 8	112.5	7.031
No. 9	102.5	6.406
No. 10	92.5	5.781
No. 11	82.5	5.156
No. 12	72.5	4.531
No. 13	62.5	3.906
No. 14	52.5	3.281
No. 16	42.5	2.656
No. 18	34.5	2.156
No. 20	26.5	1.656
No. 22	22.5	1.406
No. 24	18.5	1.156
No. 26	14.5	0.906
No. 27	13.5	0.844
No. 28	12.5	0.781
No. 29	11.5	0.719
No. 30	10.5	0.656

Method A. Acid-Alkali Method for Rapid Determination of Magnesia[1]

Solutions Required

11. The following solutions will be required:

(*a*) *Trinitrobenzene Indicator.*—Dissolve 1.0 g. of c.p. 1-3-5 trinitrobenzene in 100 ml. of ethyl alcohol (95 to 100 per cent).

(*b*) *Phenolphthalein Indicator.*—Dissolve 0.4 g. of c.p. phenolphthalein in 100 ml. of ethyl alcohol (50 per cent).

(*c*) *Standard Sodium Hydroxide Solution.*—Dissolve 13.0 g. of sodium hydroxide in water, add 10 ml. of a freshly filtered saturated barium hydroxide solution, and dilute to 1 liter with distilled water which has been recently boiled and cooled. Shake the solution from time to time for several hours, and filter into a tubulature bottle fitted with an automatic burette. Protect the solution from carbon dioxide in the air, with soda-lime tubes at the top of the bottle and the burette.

The solution as prepared is approximately $\frac{1}{3}$ *N*, and shall be standardized against acid potassium phthalate or benzoic acid acidimetric standards furnished by the National Bureau of Standards, using the methods in the certificates accompanying the standard samples. The exact normality of the solution shall be determined, and its MgO equivalent calculated on the basis that 1 ml. of a normal solution is equivalent to 0.02016 g. of MgO.

(*d*) *Standard Acid Solution.*—Dilute 32.0 ml. of HCl (sp. gr. 1.19) or 26.0 ml. of HNO_3 (sp. gr. 1.42) to 1 liter with distilled water. This solution will be slightly in excess of $\frac{1}{3}$ *N*, and shall be standardized against the standard sodium hydroxide solution, using phenolphthalein indicator, and adjusted by dilution until the two solutions are of equal strength.

(*e*) *Potassium Iodide—Starch Paper.*—Mix equal volumes of a 5 per cent potassium iodide solution and a 1 per cent soluble starch solution, and dip strips of filter paper into the mixture.

Method

12. (*a*) To 5.0 g. of cement in a 600-ml. beaker shall be added about 50 ml. of water and 50 ml. of HCl (1:1), and the solution boiled until the cement is completely in solution, excepting possibly some silica which may separate out (Note 1). Then 5 ml. of saturated bromine water shall be added and the boiling continued until the excess bromine is completely expelled, as indicated by the absence of a blue coloration on potassium iodide - starch paper when held in the issuing steam. The solution shall then be diluted to about 250 ml. with hot water and a 20 per cent solution of sodium hydroxide added to the boiling solution from a pipette, until the

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[1] This procedure is a modification of the method originally published by Fred P. Diener in *Concrete*, Vol. 39, No. 6, December, 1931. The changes, which are in minor details and do not affect the underlying principles of the method, were made by the author in cooperation with the Working Committee on Methods of Chemical Analysis of Cement of the A.S.T.M. Committee C-1 on Cement for use in the investigations sponsored by the working committee. The theory of the method is discussed in the original article.

excess acid is neutralized and a permanent precipitate just forms. Then, continuing the boiling, HCl (1:1) shall be carefully added from a pipette until the precipitate dissolves and the solution assumes a yellow ferric chloride color, avoiding much excess acid. The sides of the beaker shall be washed down with hot water and the boiling continued for a minute or two, and then the beaker shall be removed from the burner.

(*b*) To the solution shall be cautiously added 4.0 g. of calcium carbonate (weighed to the nearest 0.1 g.). This amount should be sufficient to completely neutralize the acid, with some excess. The solution shall then be diluted to about 400 ml. with hot water and boiled vigorously for 10 min. The solution shall be removed from the burner, and a 0.5 per cent potassium permanganate solution carefully added to the hot solution from a burette, with vigorous stirring, until the supernatant liquid shows a faint pink color after settling for a moment. Avoid use of more permanganate than necessary to produce a faint pink color. Then the boiling shall be continued for 2 min., 2.0 ml. of ethyl alcohol added, and the boiling continued for a few minutes or until the pink color has disappeared (Note 2).

(*c*) The contents of the beaker shall then be transferred to a 500-ml. volumetric flask, cooled to room temperature, diluted to the mark, and mixed by shaking. The solution shall be filtered through a dry paper, and after discarding the first 10 or 20 ml. of filtrate, 200 ml. of the filtrate shall be transferred with a pipette to a 500-ml. Erlenmeyer flask. The solution in the flask shall be heated to boiling, and 3.0 ml. of trinitrobenzene indicator added. Then standard sodium hydroxide solution shall be added 1.0 ml. at a time with intermittent boiling for a few seconds, until the magnesium is completely precipitated and a definite pink color persists on boiling. The total amount of alkali used shall be recorded (Note 3).

(*d*) The solution shall be transferred to a 250-ml. volumetric flask, cooled to room temperature, diluted to the mark, and mixed by shaking. The solution shall be filtered through a dry paper, into a graduated cylinder, discarding the first 10 or 20 ml. of filtrate, until 125 ml. of filtrate are secured. The 125 ml. of filtrate shall be transferred to a flask, a few drops of phenolphthalein indicator added, and the solution titrated with standard acid solution to the disappearance of the pink color.

(*e*) *Calculation.*—If the acid and alkali solutions are of equal strength, the quantity of alkali in milliliters minus twice the quantity of acid in milliliters is equivalent to the MgO in a 2-g. sample:

$$\text{MgO, per cent} = \frac{100\,(a - 2b)}{2} \times \text{MgO equivalent of 1 ml. standard alkali}$$

where a = the quantity of standard alkali in milliliters;
b = the quantity of standard acid in milliliters.

case the size of the transverse test bars is not specified, the 1.2-in. diameter bar shall be used.

Tensile Strength

7. Tension tests are not recommended as a part of these specifications except upon mutual agreement between the manufacturer and purchaser. In general, tension tests are for information only. Where tension tests are made, the tension test specimens shall be machined from that portion of the casting where specified. The dimensions of the tension test specimen will be governed by the section of the casting from which it is machined. The tensile strengths shown in Table I for plain cast iron and in Table II for alloy cast iron refer to test specimens machined from castings. If desired, by mutual agreement between the manufacturer and purchaser, tension test specimens may be machined from arbitration test bars and tested in accordance with the Tentative Specifications for Gray-Iron Castings (A.S.T.M. Designation: A 48 – 35 T) of the American Society for Testing Materials.[1]

TABLE I.—PHYSICAL PROPERTIES[a] OF PLAIN CAST IRON.

No.[b]	Hardness[c]	Transverse Strength, min., lb.	Transverse Deflection, min., in.	Tensile Strength, min., lb. per sq. in.	Uses
110	$\frac{1}{4}$-in. sections: Brinell, 192 max. Sections over $\frac{1}{4}$ in: Brinell, 163 max.	....	....	......	Miscellaneous soft iron castings
111	Brinell, 163 to 207	1800	0.20	30 000	Cylinders, flywheels, transmission cases
112	Rockwell "B," 98 to 106	....	....	....	Piston rings

[a] For more complete information on physical properties, etc., see A.F.A.-A.S.T.M. Symposium on Cast Iron, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 115 (1933).

[b] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

[c] Brinell hardness tests are to be made using 10-mm. ball and 3000-kg. load.

TABLE II.—PHYSICAL PROPERTIES[a] OF ALLOY CAST IRON.

No.[b]	Hardness[c]	Transverse Strength, min., lb.	Transverse Deflection, lb.	Tensile Strength, min., lb. per sq. in.	Uses
120	Brinell, 207 to 241	2200	0.20 min.	35 000	Cylinders
121	Brinell, 179 to 212	2700	0.27 to 0.37	40 000	Cylinders
122	Brinell, 217 to 248	3300	0.30 to 0.36	45 000	Cylinders
123	Brinell, 212 to 241	2400	0.20 to 0.30	37 500	Cylinder liners
124	Brinell, 187 to 228	....	....	......	Brake drums sprockets clutch plates
125	Brinell, 207 to 241	2500	0.24 to 0.34	37 500	
126	Brinell, 228 to 269	....	....	45 000	
127	Brinell, 187 to 228	....	....	......	Pistons

[a] For more complete information on physical properties, etc., see A.F.A.-A.S.T.M. Symposium on Cast Iron, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 115 (1933).

[b] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

[c] Brinell hardness tests are to be made using 10-mm. ball and 3000-kg. load.

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[1] See p. 713.

CHEMICAL COMPOSITION

Chemical Composition

8. (*a*) *Plain Cast Iron.*—The analyses in Table III are typical of plain cast iron but are not to be construed as required. With good foundry practice the physical properties given in Table I are usually met when the indicated analysis is used, although some variations from the suggested compositions may be necessary.

(*b*) *Alloy Cast Iron.*—The analyses in Table IV are typical of alloy cast iron but are not to be construed as required. With good foundry practice the physical properties given in Table II are usually met when the indicated analysis is used, although some variations from the suggested compositions may be necessary. Due to specific service requirements, costs, and the variables in foundry practice in influencing results, likewise, the possible variations in combinations of the alloying constituents, the kinds and amounts of the alloying elements used should be a matter of mutual agreement between the manufacturer and purchaser upon specific classes of castings. In general, one or more of the elements chromium, copper, molybdenum and nickel should be used.

TABLE III.—CHEMICAL COMPOSITION OF PLAIN CAST IRON.

No.[a]	Total Carbon, per cent	Combined Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, max., per cent	Silicon, per cent	Uses
110	3.45±0.15	......	0.60±0.10	0.30 max.	0.13	2.50±0.10	Miscellaneous soft iron castings
111	3.25±0.15	0.45±0.15	0.60±0.10	0.20 max.	0.13	2.20±0.10	Cylinders, flywheels, transmission cases
112	3.45±0.15	......	0.60±0.10	0.60±0.15	0.10	2.90±0.10	Piston rings

[a] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

TABLE IV.—CHEMICAL COMPOSITION OF ALLOY CAST IRON.

No.[a]	Total Carbon, per cent	Combined Carbon, per cent	Manganese, per cent	Phosphorus, max., per cent	Sulfur, max., per cent	Silicon, per cent	Uses
120	3.25±0.15	0.65±0.10	0.60±0.10	0.20	0.12	2.25±0.10	Cylinders
121	3.25±0.15	0.60±0.10	0.70±0.10	0.20	0.12	2.35±0.10	Cylinders
122	3.00±0.15	0.65±0.10	0.75±0.10	0.15	0.12	2.05±0.10	Cylinders
123	3.25±0.15	0.83±0.10	0.65±0.10	0.20	0.12	2.00±0.10	Cylinder liners
124	3.15±0.15	0.50±0.10	0.60±0.10	0.20	0.12	2.00±0.10	Brake drums, sprockets, clutch plates
125	3.25±0.15	0.65±0.10	0.60±0.10	0.20	0.12	2.00±0.10	
126	2.80±0.15	0.60±0.10	0.50±0.10	0.20	0.12	2.30±0.10	
127	3.40±0.15	0.40±0.10	0.60±0.10	0.20	0.12	2.30±0.10	Pistons

[a] These numbers are identical with corresponding S.A.E. numbers in the Standard Specifications for Automotive Gray-Iron Castings of the Society of Automotive Engineers.

(*d*) *Calculation.*—The percentage of magnesia in a 0.5-g. sample may be calculated as follows:

$$\text{Percentage of MgO} = [(B - C) \times A] \times 200$$

where A = the weight of MgO in grams per milliliter of standard sodium thiosulfate solution;

B = milliliters of standard sodium thiosulfate solution equivalent to 25 ml. of standard bromate solution, and

C = milliliters of sodium thiosulfate solution required in the titration.

(*e*) *Blank Determination.*—A blank determination shall be made, using the same procedure as outlined above, and using approximately the same amounts of reagents. The titration results shall be corrected accordingly.

NOTE 1.—An excess of the 8-hydroxyquinoline reagent should be used. If it is small, the result of the determination of magnesia may be low; on the other hand, if large, the result may be high. The following guide may be used:

APPROXIMATE CONTENT OF MAGNESIA, PER CENT	APPROXIMATE AMOUNT OF REAGENT REQUIRED, ML.
0 to 1.5	10
1.5 to 3.0	15
3.0 to 4.5	20
4.5 to 6.0	25

NOTE 2.—The precipitate should be filtered within an hour. Prolonged standing may cause high result.

NOTE 3.—The amount of the standard bromate solution used may be as follows:

APPROXIMATE CONTENT OF MAGNESIA, PER CENT	AMOUNT OF STANDARD BROMATE SOLUTION, ML.
0 to 1	10
1 to 2	15
2 to 3	20
3 to 4	25
4 to 5	30
5 to 6	35

TENTATIVE METHOD OF TEST
FOR
FINENESS OF PORTLAND CEMENT BY MEANS OF THE TURBIDIMETER[1]

A.S.T.M. Designation: C 115 – 34 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934.[2]

Scope

1. This method of test covers the Wagner turbidimeter[3] apparatus and procedure for determining the fineness of portland cement as represented by specific surface expressed as total surface area in square centimeters per gram of cement.

APPARATUS

Apparatus

2. The Wagner turbidimeter consists essentially of a source of light of constant intensity adjusted so that approximately parallel rays of light pass through a suspension of the cement to be tested and impinge upon the sensitive plate of a photo-electric cell. The current generated by the cell is measured with a microammeter and the indicated reading is a measure of the turbidity of the suspension. General considerations indicate that turbidity is in turn a measure of the surface area of the suspended sample of cement. The apparatus, illustrated in Figs. 1 and 2, shall consist specifically of the parts described in Sections 3 to 9.

Turbidimeter

3. The turbidimeter shall be mounted in a suitable case and shall include the following features:

(a) *Source of Light.*—The source of light (Fig. 2) shall consist of a 3 to 6 candlepower concentrated filament electric lamp operated by a 6-v. storage battery. A parabolic reflector shall be mounted behind the lamp

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-1 on Cement.

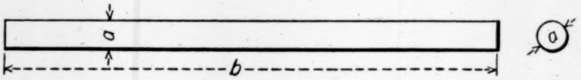
[2] Accepted for publication as tentative by Committee E-10 on Standards, December 27, 1934.

[3] This turbidimeter was developed by L. A. Wagner, Research Associate of the Cement Reference Laboratory, National Bureau of Standards, Washington, D. C. A description of the apparatus and mathematical derivations of formulas used are given in the paper, "A Rapid Method for the Determination of the Specific Surface of Portland Cement," by L. A. Wagner, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part II, p. 553 (1933).

(*b*) By mutual agreement between the manufacturer and purchaser deflection values in the transverse test may be specified (Note 4).

(*c*) The transverse breaking loads specified in Paragraph (*a*) are based on actual averages of transverse test loads for each class of casting. It is not implied by these specifications that the ratio of tensile strength to transverse load is constant. By agreement between the manufacturer and purchaser, tensile strength and transverse tests may be made and a range of transverse values determined. These values will then supersede the values specified in Paragraph (*a*).

(*d*) When an iron is specified by class (No. 20, No. 25, etc.) and the transverse test bar fails to meet the load requirements specified in Paragraph (*a*), then the manufacturer shall have the right to have tested a tension test specimen machined from a broken end of the transverse bar. In the event that this tension specimen meets the requirements of the specified class, as given in Section 2, the class requirement shall be considered as having been met, irrespective of the transverse breaking load.



Transverse Test Bar	Dimensions Diameter (*a*)	 Length (*b*)	Distance Between Supports in Transverse Test
A	0.875 in.	15 in.	12 in.
B	1.20 in.	21 in.	18 in.
C	2.00 in.	27 in.	24 in.

FIG. 1.—Transverse Test Bars.

Test Bars

4. Test bars shall be cast separately from the casting. Three standard sizes of transverse test bars are available under these specifications as shown in Fig. 1 (Note 5). Tension test specimens shall be machined from the transverse test bars to the dimensions shown in Fig. 2.

Correlation of Test Bar and Casting

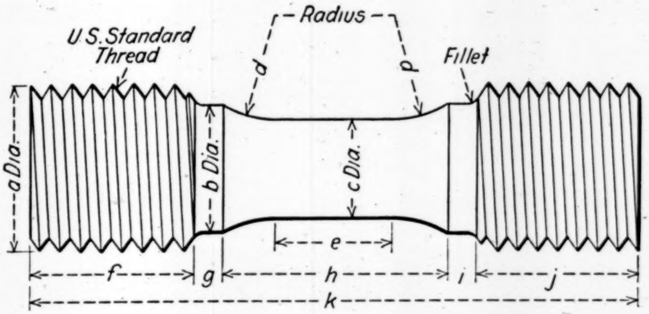
5. (*a*) The manufacturer and purchaser shall agree upon the controlling section of the casting. Then the corresponding test bar shall be used as follows:

Controlling Section of Casting	Test Bar	Nominal Diameter of Test Bar as Cast
0.50 in. and under	*A*	0.875 in.
0.51 to 1.00 in	*B*	1.20 in.
1.01 to 2.00 in	*C*	2.00 in.
Over 2.00 in	Test bar *C* may be used or a larger test bar may be used by mutual agreement between the manufacturer and purchaser	

(*b*) The correlation in Paragraph (*a*) is only approximate and may need modification for complicated castings. The test bar size for a given casting may then be determined by mutual agreement between the manufacturer and purchaser.

Molding and Pouring Test Bars

6. Unless otherwise agreed upon by the manufacturer and purchaser, test bars shall be made under the same sand conditions as the castings (Notes 6 and 7). The bars shall be poured from a ladle or ladles of iron used to pour the castings. The test bars shall receive the same mechanical and thermal treatment as the castings. In the case of heat treatment, the test bars are to be treated adjacent to the castings they represent.



DIMENSION	DIMENSIONS OF TEST BARS TEST BAR *A*	TEST BAR *B*	TEST BAR *C*
a	$\frac{3}{4}$ in.	$1\frac{1}{8}$ in.	$1\frac{7}{8}$ in.
b	$\frac{5}{8}$ in.	$\frac{15}{16}$ in.	$1\frac{7}{16}$ in.
c	0.505 in.	0.800 in.	1.25 in.
d	1.00 in.	1.00 in.	2.00 in.
e[a]	Shall be equal or greater than *c* (diameter)		
f	1.00 in.	1.00 in.	$1\frac{3}{4}$ in.
g	0.25 in.	0.25 in.	$\frac{5}{16}$ in.
h, minimum	1.25 in.	1.50 in.	$2\frac{1}{4}$ in.
i	0.25 in.	0.25 in.	$\frac{5}{16}$ in.
j	1.00 in.	1.00 in.	$1\frac{3}{4}$ in.
k, minimum	3.75 in.	4.00 in.	$6\frac{3}{8}$ in.

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[a] Length of parallel.

FIG. 2.—Tension Test Specimens Machined from Transverse Test Bar.

Tensile Strength Test Procedure

7. Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is recommended (Note 8).

Transverse Test Procedure

8. The transverse test shall be made on the bar as cast with central loading between supports. Corrections shall be made for sizes of bars as shown in Table I. Controlling dimensions shall be the diameter of the bar at the fracture. The rate of application of the load shall be such that

inside dimensions 2 by 1½ in. by 8 in. in height. The 2-in. faces of the tank shall be placed normal to the beam of light, and shall be equidistant within 0.003 in. at all points. A mark shall be placed on the side of the tank to indicate a volumetric content of 335 ml., which is the level to which the tank will be filled in a test.

(*e*) *Photo-Electric Cell.*—The means of measuring the light intensity shall be a sensitive photo-electric cell (Weston Photronic type) connected directly to a microammeter. A hood with a horizontal slot ½ in. in height by 1⅜ in. in width shall be mounted over the face of the photo-electric cell.

(*f*) *Shield.*—A metallic shield having a slot ⅝-in. in height by 1½ in. in width, as indicated in Fig. 2, shall be placed between the water cell and the sedimentation tank.

(*g*) *Elevating Device.*—The source of light, water cell, photo-electric cell, retarding filter and shield shall be mounted on a movable shelf which is raised or lowered by two connected lead screws so that the turbidity of the suspension may be determined at any desired depth. The sedimentation tank shall be mounted on a base which is independent of the rest of the apparatus so that the tank shall be free from vibration caused by moving the shelf. The level of the light beam with reference to the surface of the suspension shall be indicated by a pointer which will travel along a scale mounted on the cabinet. The zero of the scale shall indicate that position at which the center lines of the slots for the light beam are at the same elevation as the surface of the liquid in the tank when filled to the 335-ml. level. The lines on the scale to be marked 7.5, 10, 15, 20, 25, and 30-60, shall be located at distances from the zero mark equal to values "h" in Table I, and shall indicate the positions at which the pointer should be located when turbidity readings for these particle sizes are taken. The interior of the turbidimeter cabinet and the exterior surfaces of the shelf, parabolic reflector, water cell, shield and photo-electric cell hood shall be painted with a dull optical black paint.

Microammeter

4. The microammeter shall have a range of 0 to 50 microamperes, shall be readable to 0.1 microampere, and accurate to 0.25 microampere. The internal resistance of the microammeter shall be between 95 and 105 ohms.

Battery

5. A 6-v. automobile starting and lighting storage battery shall be used for supplying current to the lamp.

Sieving Apparatus

6. The sieving apparatus, consisting of a No. 325 sieve, 2 in. in diameter and having side walls 3 in. in height, shall conform to the Standard Speci-

fications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1] A spray nozzle having seventeen 0.02-in. holes in the tip shall be used for washing the sample through the sieve. A pressure gage shall be installed in the water line between the shut-off valve and the nozzle so that the pressure on the nozzle can be regulated.

Stirring Apparatus

7. The stirring apparatus shall consist of a brush, which will fit the contour of the bottom of a test tube, attached to a stirring motor. The brush shall rotate at a speed of approximately 500 r.p.m.

Timing Burette

8. The time of settling for the different sized particles shall be obtained from a burette from which kerosine is allowed to flow. The burette shall consist of a glass tube having a capillary tube fused into the lower end. The upper end of the large tube shall be flared to serve as a funnel for introducing kerosine into the tube. The burette shall conform to the following limiting dimensions:[a]

	DIMENSION, CM.	PERMISSIBLE VARIATION, CM.
Length of large tube	38	± 4
Inside diameter of large tube	1.9	± 0.2
Length of capillary	17.5	± 2.5
Diameter of capillary	0.09	± 0.005
Top of burette to zero line	7	± 1

[a] Since glass tubing of desired dimensions is not always obtainable, the above wide permissible variations allow selection of dimensions to produce a burette having a duration of flow which will permit of calibration as described in Section 10.

Suspending Liquid

9. At least 20 gal. of any clear white kerosine shall be set aside for use with the turbidimeter apparatus.

CALIBRATION OF APPARATUS

Calibration of Turbidimeter

10. The turbidimeter apparatus shall be calibrated in accordance with the following procedure:

(a) *Calibration of Burette Scale.*—For calibration of the burette scale a kerosine having a known viscosity and density for the temperature at which the calibration is to be made shall be used. The times of flow from the burette which correspond to the times of settling for the different sized particles shall be calculated from the following equation:

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

NOTE 4.—In the transverse test, it is recommended that the deflections at fracture be recorded and reported.

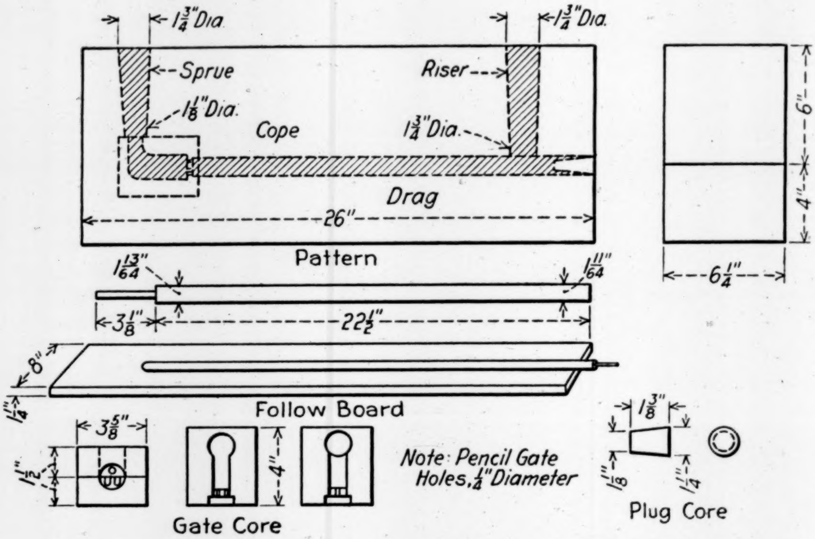
1¾" Dia
1¾" Dia
Sprue
Riser
1⅛" Dia
Cope
1¾" Dia
Drag
26"
6"
4"
6¼"
Pattern
1 13/64"
1 11/64"
3⅛"
22½"
8"
¼"
Follow Board
3⅝"
1½"
4"
Note: Pencil Gate Holes, ¼" Diameter
1⅜"
1⅛"
1¼"
Gate Core
Plug Core

FIG. A1.—Transverse Test Bar, 1.20 in. Diameter, Cast Horizontally.

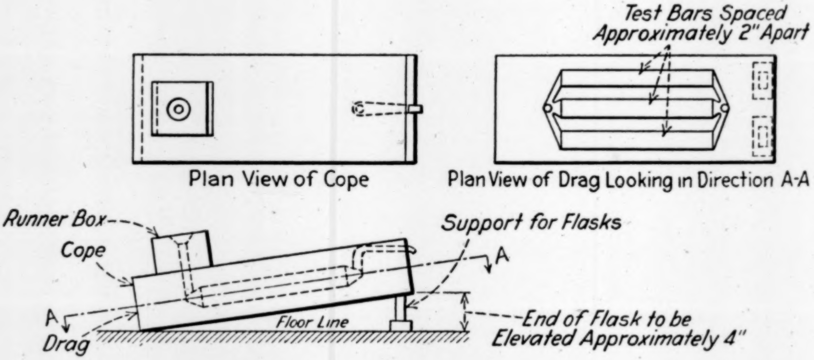
Test Bars Spaced Approximately 2" Apart
Plan View of Cope
Plan View of Drag Looking in Direction A-A
Runner Box
Cope
Support for Flasks
A
A
Drag
Floor Line
End of Flask to be Elevated Approximately 4"

FIG. A2.—Test Bar Cast on Incline.
Arrangement of Flasks for Casting Test Bars.

The modulus of rupture for any bar tested under these specifications can be ascertained by application of the following formula:

$$\text{Modulus of Rupture} = \frac{2.546\, L\, S}{D^3}$$

where L = the span length or distance between supports in inches;
S = the breaking load in pounds, and
D = the diameter of the test bar in inches.

NOTE 5.—Test bars shall be plain, cylindrical shapes as shown in Fig. 1. Where bars are cast on end, allowance for draft may be made. However, the diameter at the center of the length must correspond to the nominal diameter, within the following permissible variations:

	PERMISSIBLE VARIATIONS
Bar *A*	± 0.05 in.
Bar *B*	± 0.10 in.
Bar *C*	± 0.10 in.

Tension test specimens "cast to size" are not recognized in these specifications.

NOTE 6.—A sound test bar is desired. Several methods of making transverse test bars are shown in Figs. A1, A2 and A3. All of these methods have been used and found to produce satisfactory results. Another method of making a transverse test bar is shown in Fig. 1 of the Standard Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (A.S.T.M. Designation: A 124) of the American Society for Testing Materials.[1]

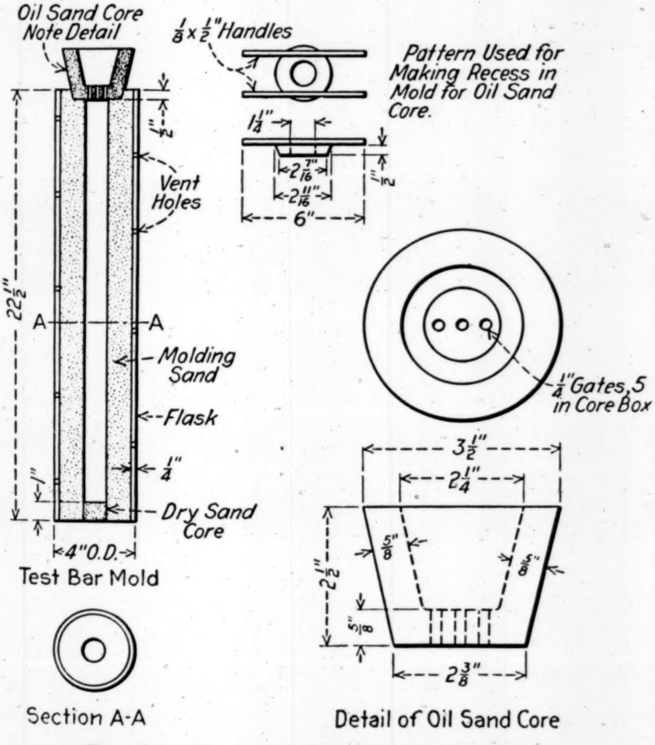
Oil Sand Core Note Detail
1/8 x 1/2" Handles
Pattern Used for Making Recess in Mold for Oil Sand Core.
1 1/4"
1/2"
2 7/16"
2 11/16"
6"
Vent Holes
22 1/2"
A
A
Molding Sand
Flask
1/4"
1"
Dry Sand Core
4" O.D.
Test Bar Mold
1/4" Gates, 5 in Core Box
3 1/2"
2 1/4"
5/8"
5/8"
2 1/2"
5/8"
2 3/8"
Section A-A
Detail of Oil Sand Core

FIG. A3.—Transverse Test Bar Cast Vertically.

NOTE 7.—Test bars shall not be cleaned by tumbling unless the castings are so cleaned, or unless mutually agreed upon by the manufacturer and purchaser.

NOTE 8.—The use of ball and socket holders in the tensile strength test is recommended. Tests made under conditions where eccentric loadings may occur will give erroneous results.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 496.

medium cement (70 to 85 per cent passing a No. 325 sieve), and 0.5 g. for a coarse cement (less than 70 per cent passing a No. 325 sieve) (Note).

NOTE.—The size of sample is selected so that the microammeter readings will fall in the middle portion of the microammeter scale.

TEST PROCEDURE

Sieve Determination

12. A No. 325 sieve determination shall be made on a 1-g. sample of the cement in accordance with the procedure specified for calibration in Section 10 (*b*). The percentage of cement passing the sieve shall be noted and recorded as ***r***.

Preparation of the Suspension

13. (*a*) The cement sample shall be placed in a test tube with 10 to 15 ml. of kerosine and 5 drops of oleic acid. (Oleic acid is added as a dispersing agent and has slight or no effect on the viscosity of the kerosine. The mixture shall then be stirred for 1 min. with the apparatus described in Section 7, and shall then be transferred to the settling tank, the brush and tube washed with clear kerosine which shall also be added to the suspension, and clear kerosine added until the total volume of the suspension in the tank is 335 ml. (Note).

NOTE.—Since it is important that the level of the liquid in the tank coincide with the zero mark on the scale of the instrument (see Section 3 (*g*)), it is correspondingly important that the volume of the suspension be close to 335 ml., as specified. This may be accurately determined by the use of a calibrated flask of 335-ml. capacity, from which all the kerosine used in making up a suspension is taken; or a point gage may be used, consisting essentially of a flat plate approximately 2 by 2½ in. to the center of which is attached vertically a metal pin of such length that, when the plate is placed in position on top of the tank, the point of the pin is at the 335-ml. level. Either of these methods should insure the position of the liquid level within a few tenths of a millimeter.

(*b*) *Agitation of the Suspension.*—The tank shall be agitated just before being placed in the path of the light beam to effect a uniformity of the suspension. The tank shall be covered with a ground-glass cover and oscillated 180 deg. about a horizontal axis at the rate of approximately one inversion per second for one minute (Note 1). Care should be taken to prevent loss of kerosine (Note 2). The suspension will then be ready to place in its proper position in the path of the light beam.

NOTE 1.—The procedure described for oscillating the suspension must be carefully followed. The procedure used in shaking a cocktail must not be used.

NOTE 2.—The faces of the glass tank may be wiped only when the tank does not contain a suspension of the cement particles. Wiping the tank may generate static electricity and interfere with the free fall of the particles.

Test Procedure

14. The turbidimeter apparatus shall be operated in accordance with the test procedure described in the following Paragraphs (*a*) to (*h*):

(*a*) With retarding filter and sedimentation tank containing approximately 100 ml. of clear kerosine in the light path, the light shall be adjusted to the proper intensity, I_0, by taking repeated readings at 1-min. intervals until an unchanging value shall indicate that the lamp and photo-electric cell are in equilibrium (Note).

NOTE.—The lamp must never be turned on without a suspension or the retarding filter in position to reduce the light intensity to a value within the range of the microammeter.

(*b*) The proper size of sample of cement (Section 11) shall be weighed and a suspension prepared in accordance with Section 13.

(*c*) The shelf level pointer shall be placed at the 30–60-micron position.

(*d*) The burette shall be filled with kerosine and oscillation started in accordance with Section 13 (*b*). The oscillation shall be continued until the kerosine drains to the zero line on the burette, when the agitation shall be stopped (Note). The tank shall be immediately placed in position in the path of the light beam.

NOTE.—The lid to the tank must fit so that no kerosine drains down the outside faces of the tank.

(*e*) The retarding filter shall be removed from the light path and the cabinet door closed.

(*f*) The microammeter shall be read at the instants the kerosine in the burette drains past marks 60, 55, 50, 45, 40, 35 and 30.

(*g*) The shelf shall then be raised successively to the marks 25, 20, 15, 10 and 7.5 on the pointer scale, the microammeter being read at each position as the kerosine drains past the corresponding mark on the burette.

(*h*) The filter shall be replaced in the path of the light beam, the tank removed and the intensity of the lamp checked (Note).

NOTE.—If the intensity of the lamp has shifted more than 0.3 microampere from the initial setting (I_0), the test must be repeated. A freshly charged storage battery should be momentarily short-circuited to reduce the voltage to constant value. If the intensity of the lamp continues to fluctuate, look for loose connections in the lamp and photo-cell circuits, see that the rheostat contacts are clean and make certain that the lamp, socket and reflector are rigidly fixed in their mounting.

CALCULATIONS

Calculation of Results

15. Calculation of the turbidimeter data shall be made in accordance with the following Paragraphs (*a*) to (*c*):

(*a*) *Specific Surface.*—Specific surface shall be calculated from the following equation:

$$S = \frac{38\,r\,(2 - \log I_{60})}{1.5 + 0.75 \log I_{7.5} + \log I_{10} + \log I_{15} + \log I_{20} \ldots\ldots\ldots\ldots\ldots + \log I_{55} - 11.5 \log I_{6}}$$

where S = the specific surface of the sample in square centimeters per gram;
r = the percentage by weight passing the No. 325 sieve, and
$I_{7.5}, I_{10}, I_{15} \ldots\ldots I_{60}$ = the microammeter readings, in microamperes, which correspond to the particle diameters 7.5, 10, 15......60 microns.

(*b*) *Recording of Data.*—The following form is suggested for the recording of turbidimeter data and calculation of specific surface:

TABLE II.—FORM FOR RECORDING TURBIDIMETER TEST DATA AND CALCULATION OF SPECIFIC SURFACE.

(Values shown are for purpose of illustration.)

Sample Identification		Sample X
Passing No. 325 Sieve (wet method), r		89.7 per cent
Filter Reference	Before Test	20.5 microamperes
	After Test	20.5 microamperes
Weight of Sample Tested		0.3 g.

PARTICLE SIZE, MICRONS	I, MICROAMPERES	LOG I
60	11.0	1.041
55	11.1	1.045
50	11.3	1.053
45	11.5	1.061
40	11.7	1.068
35	12.1	1.083
30	12.6	1.100
25	13.4	1.127
20	14.4	1.158
15	15.7	1.196
10	19.1	1.281
7.5	23.0	1.362

$0.75 \times 1.362\ (\log I_{7.5}) = 1.021$
1.500
13.693[a]
$11.5 \times 1.041\ (\log I_{60}) = 11.980$
Difference = 1.713

$$S = \frac{38 \times 89.7 \times 0.959}{1.713} = 1910 \text{ sq. cm. per gram}$$

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[a] This figure, 13.693, is the summation of column 3, excluding log $I_{7.5}$ (1.362) and log I_{60} (1.041).

(*c*) *Calculation of the Specific Surface from First Turbidity Reading,* I_{60}.—This method may be used for successive determinations from the same plant, provided, that the same size test samples are used, and that there is no great change in fineness, color, or other properties of the cement. Under these conditions the specific surface of a sample may be calculated from the first turbidity reading, I_{60}, by using the following equation:

$$S = c(2 - \log I_{60})$$

where S = the specific surface in square centimeters per gram;

I_{60} = the microammeter reading corresponding to particle diameter of 60 microns, and

c = the transmittancy constant for the particular plant.

NOTE.—The transmittancy constant "c" may be evaluated by substituting in the above equation known values of S and $2 - \log I_{60}$ as determined from a complete turbidimeter test. The average of not less than five values of "c," as determined from complete tests, should be used in the above equation.

TENTATIVE SPECIFICATIONS
FOR
BUILDING BRICK (MADE FROM CLAY OR SHALE)[1]

A.S.T.M. Designation: C 62 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED. 1935.

1. These specifications cover brick made from clay or shale and properly burned, intended for use in brick masonry. Seven grades of brick are covered, as follows:

Grades A, B and C.—These grades are classified according to strength only.

Grades AW-1 and BW-1.—Bricks intended for use where exposed to very severe weathering, such as severe frost action.

Grades AW-2 and BW-2.—Bricks intended for use where exposed to weathering.

Properties

2. (*a*) The bricks shall conform to the physical requirements for the grade specified as follows:

Grade	Compressive Strength (bricks flatwise), lb. per sq. in., average gross area		Modulus of Rupture (bricks flatwise), lb. per sq. in., average gross area		Water Absorption by 5-hr. boiling, per cent	C/B ratio[a]
	Average of 5 bricks	Individual Minimum	Average of 5 bricks	Individual Minimum	Individual Maximum	Individual Maximum
Grade *A*	4500 or more	3500	600 or more	400	......	......
Grade *B*	2500 – 4500	2000	450 or more	300	......	......
Grade *C*	1250 – 2500	1000	300 or more	200	......	......
Grade *AW-1*	4500 or more	3500	......	......	20	0.80
Grade *BW-1*	2500 – 4500	2500	......	......	20	0.80
Grade *AW-2*	4500 or more	3500	......	......	20	0.85
Grade *BW-2*	2500 – 4500	2500	......	......	20	0.85

[a] The ratio *C/B* is the ratio of absorption by 24-hr. submergence in cold water to that after 5 hr. in boiling water.

(*b*) Unless otherwise specified by the purchaser, bricks of grades *A* and *B* shall be accepted in lieu of grade *C*, grade *A* in lieu of grade *B*, grades *AW-1*, *BW-1* and *AW-2* in lieu of grade *BW-2*, and grade *AW-1* in lieu of grade *AW-2* or *BW-1*.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-3 on Brick.

These Tentative Specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Building Brick (Made from Clay or Shale) (A.S.T.M. Designation: C 62 – 30), 1933 Book of A.S.T.M. Standards, Part II, p. 109.

Test Specimens

3. For purpose of tests, bricks representative of the commercial product shall be selected by a competent person appointed by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or purchaser shall furnish specimens for tests without charge. All bricks shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than ten brick shall be required for each investigation. In general, two samples of ten brick each shall be tested for each 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, one sample of 10 brick from each 100,000 shall be tested. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

Standard Sizes

4. The standard sizes of brick made from clay or shale shall conform to the following dimensions, within permissible variations of $\pm\frac{1}{16}$ in. in depth, $\pm\frac{1}{8}$ in. in width, and $\pm\frac{1}{4}$ in. in length:

TYPE	DEPTH, IN.	WIDTH, IN.	LENGTH, IN.
Common brick........................	$2\frac{1}{4}$	$3\frac{3}{4}$	8
Rough-face brick....................	$2\frac{1}{4}$	$3\frac{3}{4}$	8
Smooth-face brick..................	$2\frac{1}{4}$	$3\frac{7}{8}$	8

Workmanship and Finish

5. When any particular surface appearance or uniformity is desired, it shall be as mutually agreed upon by the manufacturer and purchaser.

Visual Inspection

6. All brick shall conform to the following requirements for general properties under visual inspection:

(*a*) They shall be free from cracks, warpage, stones, pebbles, or particles of lime that would affect their serviceability or strength.

(*b*) Bricks of grade *A* or grade *B* when struck together shall give a ringing sound.

Rejection

7. If the visual inspection (Section 6) appears to indicate inferior strength, the brick may be rejected unless the physical tests show the quality or grade to be as specified.

Acceptance

8. At the option of the purchaser, acceptance may be based on the visual inspection requirements specified in Section 6 and the results of one of the strength tests (compressive strength or modulus of rupture) specified

in Section 2. While the compressive strength is considered as generally giving the better basis for classification purposes, the flexure test gives important information on the strength and proper manufacturing details.

Methods of Testing

9. The bricks shall be tested in accordance with the Tentative Methods of Testing Brick (Modulus of Rupture, Compressive Strength, Absorption) (A.S.T.M. Designation: C 67 – 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 791.

TENTATIVE METHODS OF TESTING BRICK[1]

(MODULUS OF RUPTURE, COMPRESSIVE STRENGTH, ABSORPTION)

A.S.T.M. Designation: C 67 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Scope

1. These methods cover the following tests for brick:

Modulus of rupture (flexure test)
Compressive strength
Absorption

Definition of Terms

2. The Standard Definitions of Terms Relating to Methods of Testing (A.S.T.M. Designation: E 6) of the American Society for Testing Materials,[2] shall be considered as applying to the terms used in these methods.

Modulus of Rupture (Flexure Test)

Appraratus

3. The testing machine, or other calibrated testing device, used for the flexure test of brick shall conform to the requirements of the Tentative Methods of Verification of Testing Machines (A.S.T.M. Designation: E 4 - 35 T) of the American Society for Testing Materials.[3]

Test Specimen

4. The test specimen shall consist of a whole brick. The specimen shall be dried to constant weight at a temperature of 100 to 105 C. (212 to 221 F.). It shall be cooled to room temperature before testing.

Number of Specimens

5. Flexure tests shall be made on at least five test specimens.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-3 on Brick.

These tentative methods are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Methods of Testing Brick (Compression, Flexure, Absorption) (A.S.T.M. Designation: C 67 - 31), 1933 Book of A.S.T.M. Standards, Part II, p. 128.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1248.

[3] See p. 1303.

Flexure Test

6. (*a*) The test specimen shall be supported flatwise on a span of 7 in. and loaded at mid-span. The load shall be applied to the upper surface of the specimen through a steel bearing plate $\frac{1}{4}$ in. in thickness and $1\frac{1}{2}$ in. in width and of a length at least equal to the width of the specimen. The direction of the load shall be perpendicular to the loaded surface of the specimen.

(*b*) The supports for the test specimen shall be free to rotate in the longitudinal and transverse direction of the test specimen and shall be adjusted so that they will exert no force in these directions.

(*c*) The speed of the moving head of the testing machine (or other calibrated testing device) during the application of the load shall not exceed 0.05 in. per min.

Modulus of Rupture

7. (*a*) The modulus of rupture of each specimen shall be calculated by the use of the following formula:

$$\text{Modulus of rupture, lb. per sq. in.} = \frac{3Wl}{2bd^2}$$

where W = the maximum load indicated by the testing machine, in pounds;
l = the distance between the supports in inches (7 in.);
b = the average over-all breadth, face to face, of the specimen, in inches, and
d = the average over-all depth, face to face, of the specimen, in inches.

(*b*) The average of the modulus of rupture determinations of all the specimens tested shall be reported as the modulus of rupture of the lot of brick.

COMPRESSIVE STRENGTH TEST

Apparatus

8. (*a*) The testing machine used for the compressive strength test of brick shall conform to the requirements of the Tentative Methods of Verification of Testing Machines (A.S.T.M. Designation: E 4 - 35 T) of the American Society for Testing Materials.[1]

(*b*) The testing machine shall be equipped with a lubricated spherical bearing block.

Test Specimen

9. The test specimen shall consist of a half-brick, with approximately plane and parallel ends. The specimen may be obtained from a whole brick by any method that will produce, without shattering, a half-brick.

NOTE.—This permits the use of suitable half-bricks available after the transverse test has been made.

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[1] See p. 1303.

Number of Specimens

10. Compressive strength tests shall be made on at least five test specimens, each from a different brick.

Preparation of Specimen

11. (*a*) If the flatwise faces of the test specimen are recessed or paneled, the depressions shall be filled with a neat Portland cement paste, which shall then be allowed to age at least 24 hr. before the specimen is capped.

(*b*) The two opposite flatwise faces of each specimen shall be coated with shellac which shall be allowed to dry thoroughly.

(*c*) One of the dry shellacked faces of the specimen shall be bedded in a thin coat of a neat paste of calcined gypsum (plaster of Paris) which has been spread on an oiled non-absorbent plate such as glass or a machined metal plate. This procedure shall be repeated with the other dry shellacked face. Care shall be taken that the opposite bearing surfaces so formed will be approximately parallel. The capping shall be allowed to age at least 2 hr. before the compression test is made.

Compression Test

12. (*a*) The specimen shall be tested flatwise (that is, the load shall be applied in the direction of the thickness of the brick).

(*b*) The spherical bearing block shall be placed between a capped face of the specimen and the platen of the testing machine. If a vertical testing machine is used, the spherical bearing shall be placed on top of the specimen. The center of the spherical surface of the block shall be in the plane of the bearing surface of the specimen and in an axis of the specimen. The spherical bearing block shall be adjusted by rotating it under a small initial load.

(*c*) When the load on the specimen exceeds approximately one-half of the maximum load, the rate of loading shall be such that the load will be read accurately. Preferably, the rate of loading should not exceed 2000 lb. per sq. in. per min., but this requirement may be considered as being met if the speed of the moving head of the testing machine during the application of the load is not more than 0.05 in. per min.

Compressive Strength

13. (*a*) The compressive strength of each specimen shall be calculated by the use of the following formula:

$$\text{Compressive strength, lb. per sq. in.} = \frac{W}{A}$$

where W = the maximum load indicated by the testing machine, in pounds, and

A = the average of the gross areas of the upper and lower bearing surfaces of the specimen, in square inches.

(*b*) The average compressive strength of all the specimens tested shall be reported as the compressive strength of the lot of brick.

ABSORPTION TEST

24-Hour Immersion Test

Test Specimen

14. A test specimen shall consist of a half-brick conforming to the requirements of Section 9.

Number of Specimens

15. Absorption tests shall be made on at least five test specimens.

Absorption Test

16. (*a*) The test specimen shall be dried to constant weight at a temperature of 100 to 105 C. (212 to 221 F.).

(*b*) When cool, the specimen shall be weighed on scales or balances sensitive to within 0.1 per cent.

(*c*) The dry specimen shall be submerged in clear water (soft, distilled or rain water) at a temperature of 15.5 to 30 C. (60 to 86 F.) for 24 hr. The specimen shall then be removed, the surface water wiped off with a damp cloth, and the specimen quickly weighed.

Absorption

17. (*a*) The absorption of each specimen shall be calculated by the use of the following formula:

$$\text{Absorption, per cent} = \frac{100\,(b-a)}{a}$$

where a = the dry weight of the specimen, and
b = the saturated weight of the specimen.

(*b*) The average absorption of all the specimens tested shall be reported as the absorption of the lot of brick.

5-Hour Boiling Test

Test Specimen

18. A test specimen shall consist of a half-brick conforming to the requirements of Section 9.

Number of Specimens

19. Absorption tests shall be made on at least five test specimens.

Absorption Test

20. (*a*) If a dry test specimen is used it shall be dried to constant weight at a temperature of 100 to 105 C. (212 to 221 F.). In lieu of making the 5-hr. boiling test on a dry test specimen, the specimen, which has been

saturated 24 hr. in the cold-water immersion bath, may be returned to the bath and subjected to a 5-hr. boiling test as described in Paragraph (*c*).

(*b*) When cool, the specimen shall be weighed on a scale or balance sensitive to within 0.1 per cent.

(*c*) The dry specimen shall be submerged in clear water (soft, distilled or rain water) at a temperature of 15.5 to 30 C. (60 to 86 F.). The water shall be heated to boiling within 1 hr., boiled continuously for 5 hr. and then allowed to cool to a temperature of 15.5 to 30 C. (60 to 86 F.). The specimen shall then be removed, the surface water wiped off with a damp cloth, and the specimen quickly weighed.

Absorption

21. (*a*) The absorption of each specimen shall be calculated by the use of the following formula:

$$\text{Absorption, per cent} = \frac{100\,(b-a)}{a}$$

where: a = the dry weight of the specimen, and
b = the saturated weight of the specimen.

(*b*) The average absorption of all the specimens tested shall be reported as the absorption of the lot of brick.

TENTATIVE SPECIFICATIONS
FOR
STRUCTURAL CLAY FLOOR TILE[1]

A.S.T.M. Designation: C 57 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1924; ADOPTED IN AMENDED FORM, 1927; REVISED, 1930, 1931; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications apply to structural clay floor tile made from surface clay, shale, fire clay or admixtures thereof, and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.

Classification

2. (*a*) According to the results of physical tests, tile to be used in flat or segmental arches or used to resist stresses in combination tile and concrete ribbed slab construction, shall be classified as 5–16 and 16–25 on the basis of the following strength and absorption requirements:

Class	Absorption, per cent			Compressive Strength Based on Net Area,[a] lb. per sq. in.			
	Average of 5 Tests	Individual Maximum	Individual Minimum	End-Construction Tile		Side-Construction Tile	
				Average of 5 Tests	Individual Minimum	Average of 5 Tests	Individual Minimum
5 -16...........	5 to 16	19	4	3200 or more	2250	1600 or more	1100
16–25...........	25 or less	28	4	2000 or more	1400	1200 or more	850

[a] Net area of a unit shall be taken as the area of solid material in shells and webs actually carrying stresses in a direction parallel to direction of loading.

(*b*) Where end-construction tile are used on the side they shall conform to the requirements of that construction, and *vice versa*.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-10 on Hollow Masonry Building Units.

These specifications are in effect a revision of, and replace the former Standard Specifications and Tests for Structural Clay Floor Tile (A.S.T.M. Designation: C 57 - 31), which standard was accordingly discontinued in 1934.

Weights

3. (*a*) Flat and segmental arch tile shall conform to the following requirements as to minimum number of cells in depth of arch and average dry weights per square foot of tile:

FLAT ARCH TILE

DEPTH OF ARCH, IN.	MINIMUM NUMBER OF CELLS IN DEPTH OF ARCH	AVERAGE DRY WEIGHT, LB. PER SQ. FT. OF TILE	
		MINIMUM	MAXIMUM
6	1	25	29
7	1	28	34
8	2	30	36
9	2	31	37
10	2	33	39
11	2	36	43
12	2	38	45
13	3	41	48
14	3	44	52
15	3	45	53
16	3	49	58
SEGMENTAL ARCH TILE			
6	2	28	34
8	2	34	40

(*b*) Tile designed to resist stresses in combination tile and concrete ribbed slab construction shall conform to the following requirements as to minimum number of cells in the direction of depth of slab and average dry weights per square foot of tile:

THICKNESS OF UNITS, IN.	MINIMUM NUMBER OF CELLS IN THICKNESS OF TILE	AVERAGE DRY[a] WEIGHTS, LB. PER SQ. FT. OF TILE	
		MINIMUM	MAXIMUM
3	1	13.5	16.5
4	1	14.5	17.5
5	1	17.0	21.0
5	2	20.5	25.5
6	1	20.0	24.0
6	2	22.5	27.5
7	1	21.5	26.5
7	2	24.5	29.5
8	1	24.5	29.5
8	2	26.0	32.0
9	2	28.0	34.0
9	3	32.5	39.5
10	2	29.5	36.5
10	3	34.0	42.0
12	2	36.0	44.0
12	3	40.5	49.5

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[a] The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 0.5 lb. per square foot of smooth area.

Permissible Variations in Dimensions

4. No dimension shall vary more than ± 3 per cent from the specified dimensions for any form of tile.

Color

5. Color of tile varies with the type of clay used and degree of burning; hence, it cannot be taken as indicative of classification until after it has been related to absorption and strength by actual tests.

Workmanship

6. All tile shall be reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring

7. Surfaces of all tile intended for the direct application of plaster shall be scratched or scored. When scored, each groove shall be not less than $\frac{1}{8}$ in. nor more than $\frac{3}{16}$ in. in depth, nor more than 1 in. in width. The area covered by the grooves shall not exceed 50 per cent of the area of the scored faces.

Marking

8. All tile shall bear the initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

Inspection

9. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified in Sections 2 to 8, inclusive. All tests shall be made in accordance with the methods specified in Section 12.

Rejection

10. (*a*) Individual tile shall be rejected for failure to meet the weight, size, or workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

Acceptance

(*b*) By agreement, acceptance may be based on dry weight of the units, percentage of absorption, and the workmanship and finish.

Expense of Tests

11. Except as specified in Section 10 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

12. Tile shall be sampled and tested in accordance with the Tentative Methods of Sampling and Testing Structural Clay Tile (A.S.T.M. Designation: C 112 - 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 807.

TENTATIVE SPECIFICATIONS

FOR

STRUCTURAL CLAY NON-LOAD-BEARING TILE[1]

A.S.T.M. Designation: C 56 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1924; ADOPTED IN AMENDED FORM, 1930; REVISED, 1931;
REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications apply to structural clay partition, fireproofing and furring tile made from surface clay, shale, fire clay or admixtures thereof, and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.

Classification

2. According to results of physical tests, tile shall be classified as 5–16 and 16–25 on the basis of the following absorption requirements:

CLASS	ABSORPTION, PER CENT		
	AVERAGE OF FIVE TESTS	INDIVIDUAL MAXIMUM	INDIVIDUAL MINIMUM
5–16	5 to 16	19	4
16–25	16 to 25	28	4

Weights

3. Partition and split-furring tile shall conform to the following requirements as to minimum number of cells and dry weights per square foot of tile:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-10 on Hollow Masonry Building Units.

These specifications are in effect a revision of, and replace the former Standard Specifications and Tests for Structural Clay Fireproofing, Partition and Furring Tile (A.S.T.M. Designation: C 56 - 31), which standard was accordingly discontinued in 1934.

PARTITION TILE

DIMENSIONS, IN.	MINIMUM NUMBER OF CELLS IN UNIT	MINIMUM NUMBER OF CELLS IN DIRECTION OF WALL THICKNESS	MINIMUM AVERAGE WEIGHT,[a] LB. PER SQ. FT. OF TILE	MAXIMUM AVERAGE WEIGHT,[a] LB. PER SQ. FT. OF TILE	INDIVIDUAL MINIMUM WEIGHT,[a] LB. PER SQ. FT. OF TILE
2 by 12 by 12.............	3	1	14	16	13
3 by 12 by 12.............	3	1	15	17	14
4 by 12 by 12.............	3	1	16	18	15
6 by 12 by 12.............	3	1	22	25	21
6 by 12 by 12.............	4	2	25	28	24
8 by 12 by 12.............	4	2	30	34	28
10 by 12 by 12.............	4	2	35	40	33
12 by 12 by 12.............	4	2	40	45	38
SPLIT FURRING TILE					
1½ by 12 by 12............	3	..	7½	8½	7
2 by 12 by 12............	3	..	8	9	7½

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[a] The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 0.5 lb. per square foot of smooth area.

Permissible Variations in Dimensions

4. No dimension shall vary more than ± 3 per cent from the specified dimensions for any form of tile.

Color

5. Color of tile varies with the type of clay used and degree of burning; hence, it cannot be taken as indicative of classification until after it has been related to absorption and strength by actual tests.

Workmanship

6. All tile shall be reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring

7. Surfaces of all tile intended for the direct application of plaster or stucco shall be scratched or scored. When scored, each groove shall be not less than $\frac{1}{8}$ in. nor more than $\frac{3}{16}$ in. in depth, nor more than 1 in. in width. The area covered by the grooves shall not exceed 50 per cent of the area of the scored faces.

Marking

8. All tile shall bear the initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

Inspection

9. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified in the contract. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified in Sections 2 to 8, inclusive. All tests shall be made in accordance with the methods specified in Section 12.

Rejection

10. (*a*) Individual tile shall be rejected for failure to meet the weight, size, or workmanship and finish requirements. In case of failure to meet the absorption requirements for the class specified, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the test requirements, the entire lot shall be rejected.

Acceptance

(*b*) By agreement, acceptance may be based on dry weight of the units, percentage of absorption, and the workmanship and finish.

Expense of Tests

11. Except as specified in Section 10, and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

12. Tile shall be sampled and tested in accordance with the Tentative Methods of Sampling and Testing Structural Clay Tile (A.S.T.M. Designation: C 112 – 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 807.

TENTATIVE SPECIFICATIONS
FOR
STRUCTURAL CLAY LOAD-BEARING WALL TILE[1]

A.S.T.M. Designation: C 34 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1921; ADOPTED IN AMENDED FORM, 1926;
REVISED, 1927, 1930, 1931; REISSUED AS TENTATIVE, 1933;
REVISED, 1934, 1935.[2]

Scope

1. These specifications apply to structural clay load-bearing wall tile made from surface clay, shale, fire clay or admixtures thereof, and cover only physical requirements. If a purchaser desires tile having a particular color, texture, or finish, such features should be covered by separate specifications.

Classification

2. (*a*) According to results of physical tests, tile shall be classified as 5–16 and 16–25 on the basis of the following strength and absorption requirements:

Class	Absorption, per cent			Compressive Strength Based on Gross Area,[a] lb. per sq. in.			
	Average of 5 Tests	Individual Maximum	Individual Minimum	End-Construction Tile		Side-Construction Tile	
				Average of 5 Tests	Individual Minimum	Average of 5 Tests	Individual Minimum
5-16...........	5 to 16	19	4	1400 or more	1000	700 or more	500
16-25...........	25 or less	28	4	1000 or more	700	700 or more	500

[a] Gross area of a unit shall be the total area of a section including cells perpendicular to the direction of loading Re-entrant spaces are included in the gross area, unless these spaces are to be occupied in masonry by portions of adjacent units.

(*b*) Where end-construction tile are used on the side they shall conform to the requirements of that contruction, and *vice versa*.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-10 on Hollow Masonry Building Units.

These specifications are in effect a revision of, and replace the former Standard Specifications and Tests for Structural Clay Load-Bearing Wall Tile (A.S.T.M. Designation: C 34 – 31), which standard was accordingly discontinued in 1934.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

(*c*) Where tile is used in interior construction or as back-up for exposed walls with a facing of 3 in. or more of stone, terra cotta, brick or other facing, the requirements for average and individual maximum absorption shall be waived unless otherwise specified by the purchaser.

(*d*) Bonding tile shall be so designed as to provide recesses for header brick courses when laid up in brick-faced walls.

Weights and Number of Cells

3. (*a*) Load-bearing tile shall conform to the following requirements as to minimum number of cells[a] in the direction of wall thickness and dry weights per square foot of tile:

Nominal Horizontal Thickness of Tile as Laid in Wall, in.	Minimum Number of Cells in Direction of Wall Thickness	Minimum Average Weight,[b] lb. per sq. ft. of Tile	Maximum Average Weight,[b] lb. per sq. ft. of Tile	Individual Minimum Weight,[b] lb. per sq. ft. of Tile
4	1	20	23	19
6	2	30	35	28
8	2	36	41	34
10	2	42	48	40
12	3	52	60	49

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[a] Hollow spaces enclosed within the perimeter of the exterior shells and having a minimum dimension of not less than ½ in. and a cross-sectional area of not less than 1 sq. in.

[b] The weights given in the table are for scored tile. If any of the faces are smooth, the weights shall be increased 1 lb. per square foot of smooth area.

(*b*) The area of bonding tile shall be calculated on the basis of the average height of the two vertical faces as laid in the wall.

(*c*) In double-shell tile the two voids between exterior and interior shells on either side of the tile shall be considered as one cell in thickness of wall when their combined width is not less than ½ in., provided the short webs between the inner and outer shells are not greater in number or thickness than the long transverse webs holding the inner shells.

(*d*) Re-entrant spaces not less than 1 in. in depth and not less than 1 sq. in. in area, which form cells when the units are laid in the wall, shall be considered as cells in the direction of wall thickness, but not in the units.

Permissible Variations in Dimensions

4. (*a*) The thickness of bonding and other types of tile manufactured for use in combination with brick or other materials may vary from the nominal thicknesses specified in Section 3, as required by construction requirements, but no dimensions shall vary more

than ± 3 per cent from the purchasers' or manufacturers' specified dimensions.

(*b*) The average over-all thickness of the shells measured between the inner and extreme outer surfaces of end-construction load-bearing tile shall be at least $\frac{3}{4}$ in., except in double-shell tile the combined average over-all thickness of the inner and outer shell shall be not less than $\frac{3}{4}$ in. The minimum thickness of the webs shall be not less than $\frac{1}{2}$ in.

(*c*) The width of cells in side-construction tile, measured in the direction of wall thickness, shall not exceed five times the average over-all thickness of either the upper or lower bearing shells.

Weathering Resistance

5. All tile which will be subjected to weathering conditions or intended to be stuccoed shall be able to withstand 100 alternate freezings and thawings. Tile classed as 5–16 by these specifications may be considered as meeting the weathering requirements, provided they are burned to a normal maturity for the given clay. Tile classed as 16–25 shall be accepted as meeting the weathering requirements only on the basis of freezing-and-thawing tests.

Color

6. Color of tile varies with the type of clay used and degree of burning; hence, it cannot be taken as indicative of classification until after it has been related to absorption and strength by actual tests.

Workmanship

7. All tile shall be reasonably free from laminations and from such cracks, blisters, surface roughness, and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

Scoring

8. Surfaces of all tile intended for the direct application of plaster or stucco shall be scratched or scored. When scored, each groove shall be not less than $\frac{1}{8}$ in. nor more than $\frac{1}{4}$ in. in depth, nor more than 1 in. in width. The area covered by the grooves shall not exceed 50 per cent of the area of the scored faces.

Marking

9. All load-bearing tile shall bear the word "Load-Bearing" or "L-B," and name, initials or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

Inspection

10. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified in Sections 2 to 9, inclusive. All tests shall be made in accordance with the methods specified in Section 13.

Rejection

11. Individual tile shall be rejected for failure to meet the weight, number of cells, specified size, or workmanship and finish requirements, but tiles that are overweight may be accepted at the discretion of the purchaser. In case of failure to meet the absorption and strength requirements for the class specified, the manufacturer may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the manufacturer. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

Expense of Tests

12. Except as specified in Section 11 and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

Methods of Testing

13. Tile shall be sampled and tested in accordance with the Tentative Methods of Sampling and Testing Structural Clay Tile (A.S.T.M. Designation: C 112 – 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 807.

TENTATIVE METHODS OF SAMPLING AND TESTING STRUCTURAL CLAY TILE[1]

A.S.T.M. Designation: C 112 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.[2]

SAMPLING

Selection of Test Specimens

1. Specimens of tile for purpose of tests shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the specimens shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases.

Number of Specimens

2. For the weight, strength and/or absorption determinations, a total of at least five individual tile specimens shall be selected from each kiln or from each 100-ton lot. In no case shall less than five tile be taken. If specimens are required for the freezing-and-thawing tests, they shall be taken from tile that have not been subjected to strength tests.

Time and Place of Selecting Specimens

3. Specimens of tile for purpose of tests shall be selected at the factory or at the site of the work, as specified. If the freezing-and-thawing tests are to be made it shall be so specified at the time of placing the order, specimens being selected at the factory 90 days in advance of the time of filling the order.

Identification

4. All specimens selected for purpose of tests shall be plainly and permanently marked for reference by the testing operator.

WEIGHT DETERMINATIONS

Test Specimens

5. Five full-size tile specimens shall be tested.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee C-10 on Hollow Masonry Building Units.

These methods were formerly published with the Standard Specifications for Structural Clay Tile (C 34, C 56 and C 57) and were issued separately in 1934 under the present designation.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

Weight Determinations

6. The five tile specimens, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100 C. (212 F.) and shall then be weighed separately.

Accuracy of Weighings

7. The balance used shall be sensitive to within 0.5 per cent of the weight of the smallest specimen tested.

Calculating and Reporting Results

8. (*a*) The weight per unit area of a tile specimen shall be calculated by dividing the total weight in pounds by the average area of the two faces of the tile as laid in the masonry.

(*b*) The results shall be reported separately for each specimen, with the average for the five specimens.

COMPRESSIVE STRENGTH TESTS

Test Specimens

9. Five dry full-size tile specimens shall be tested.

Capping Test Specimens

10. (*a*) Bearing surfaces of the test specimens and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plain surface which has been coated with oil. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $\frac{1}{8}$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) When specimens have irregular bearing surfaces, they shall be brought approximately to the same horizontal planes by means of steel bearing plates not less than $\frac{1}{2}$ in. in thickness set in capping mortar, mixed as specified in Paragraph (*a*) with bed joints not more than $\frac{1}{8}$ in. in average thickness.

(*d*) Cement-gypsum capping shall be aged at least 3 days before the specimens are tested. If the tests must be made sooner, the specimens may be capped with a neat mortar of unretarded gypsum. Gypsum caps shall be aged at least 1 hr. before the specimens are tested. If the specimens tested with gypsum caps fail to meet the strength requirements, other specimens from the same lot shall be tested with the cement-gypsum caps aged at least 3 days.

Procedure

11. (*a*) *Position of Specimens.*—All specimens shall be tested in a position such that the load is applied in the same direction as in service.

(*b*) *Bearing Block.*—A spherical bearing block of proper design shall be placed on top of the test specimen.

(*c*) *Speed of Testing.*—The speed of the moving head of the testing machine shall not be more than 0.05 in. per min.

Calculating and Reporting Results

12. (*a*) The compressive strength of load-bearing wall tile shall be taken as the maximum load in pounds divided by the gross cross-sectional area of the tile in square inches. The gross area of a tile is the total area of a section perpendicular to the direction of the load, including areas within cells and within re-entrant spaces unless these spaces are to be occupied in the masonry by portions of adjacent masonry.

(*b*) The compressive strengths of floor tile and/or non-load-bearing tile shall be taken as the maximum load in pounds, divided by the net cross-sectional area in square inches. The net area of a tile is the area of the fired clay in the section of minimum area taken perpendicular to the direction of the load.

(*c*) The results shall be reported separately for each specimen, with the average for the five specimens.

ABSORPTION TESTS

Test Specimens

13. (*a*) The specimens for the absorption test shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used, two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. (0.5 lb.). The specimens shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

Identification

(*b*) Each specimen shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5 per cent of the total superficial area of the specimen shall be used.

Accuracy of Weighings

14. The balance used shall be sensitive to within 0.2 per cent of the weight of the smallest specimen tested.

Procedure

15. (*a*) *Drying.*—All specimens shall be dried to constant weight in a drier or oven at a temperature of not less than 100 C. (212 F.).

(*b*) *Saturation.*—After obtaining the dry weight of the specimens they shall be immersed in soft, distilled or rain water, the temperature raised to the boiling point and the water boiled continuously for 1 hr. The specimens shall then be allowed to cool in the water to room temperature.

(*c*) *Weighing.*—After saturation, the specimens shall be removed from the water and allowed to drain for not more than 1 min. The superficial water shall then be removed from the specimens with a damp cloth, after which they shall be weighed immediately.

Calculating and Reporting Results

16. The absorption shall be calculated as a percentage of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile.

FREEZING-AND-THAWING TESTS

Preparation of Specimens

17. The specimens for the freezing-and-thawing test shall consist of five tile or of a cell not less than 4 in. in length sawed from each of these five tile. The specimens shall be saturated by immersion in cold water for at least 72 hr. prior to starting the freezing.

Procedure

18. Any practical method of obtaining alternate freezings and thawings may be used, the freezings to be always made with fully saturated specimens and the time and temperature to be such as to insure full freezing and thawing throughout the specimen. The initial weighing and all weighings for loss of weight shall be made on dry specimens.

Accuracy of Weighings

19. The balance used shall be sensitive to within 0.1 per cent of the weight of the smallest specimen tested.

Interpretation of Results

20. Failure under the freezing-and-thawing treatment shall be considered to be reached when:

(*a*) The specimens show superficial disintegration or spalling with loss of weight of more than 5 per cent of the initial weight; or

(*b*) The specimens are badly cracked; or

(*c*) The specimens show evident loss of structural strength.

TENTATIVE DEFINITIONS OF TERMS RELATING TO REFRACTORIES[1]

A.S.T.M. Designation: C 71 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Insulating Fire Brick.—A product with low heat conductivity suitable for use as a lining for furnaces.

Insulating Brick.—A product manufactured in standard brick shapes used primarily for heat insulating purposes.

Calcining.—In the case of refractories manufacture, the heat treatment of raw materials preparatory to incorporation in a refractory mix to a temperature high enough to remove volatile and combustible constituents and produce incipient vitrification.

Burning (*Firing*).—In the case of refractories manufacture, the heat treatment of a refractory mix at a temperature high enough to develop a bond by partial vitrification.

Grog Fire-Clay Mortar.—Raw fire clay mixed with calcined fire clay, or with broken fire-clay brick, or both, all ground to suitable fineness.

Hard Burned, Medium Burned, Light Burned.—In the case of refractories manufacture, these terms refer to decreasing degree of intensity of heat treatment in the order named.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee C-8 on Refractories.

These definitions, when adopted as standard, will be added to the Standard Definitions of Terms Relating to Refractories (A.S.T.M. Designation: C 71 - 31), 1933 Book of A.S.T.M. Standards, Part II, p. 189.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE IRRIGATION PIPE[1]

A.S.T.M. Designation: C 118 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover concrete pipe intended to be used for the construction of irrigation lines.

Class

2. Pipe manufactured under these specifications shall be known as "Standard Concrete Irrigation Pipe."

Alternative Design

3. Manufacturers may submit to the purchaser, for approval, designs other than those given in Table I. In no alternative design, however, shall the test requirements be less than those given in Table I.

Acceptability and Basis of Acceptance

4. The acceptability of the pipe shall be determined by the results of the hydrostatic tests specified in Sections 16 and 17 and Table I and by inspection to determine whether or not the pipe conforms to these specifications as to design and freedom from defects.

MATERIALS

Concrete

5. The concrete shall consist of portland cement, mineral aggregates and water.

Cement

6. Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9) of the American Society for Testing Materials.[2]

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-13 on Concrete Pipe.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 3.

Fine Aggregate

7. (*a*) Fine aggregate shall consist of sand, stone, screenings, or other approved inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, or organic matter, loam or other deleterious substances. Fine aggregate shall be well graded and shall pass a $\frac{1}{4}$-in. screen.

Coarse Aggregate

(*b*) Coarse aggregate shall consist of crushed stone, gravel, or other inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles, free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic, or other deleterious matter. Coarse aggregate shall contain no particles having a maximum dimension exceeding one-half the thickness of the shell of the pipe.

TABLE I.—STANDARD CONCRETE IRRIGATION PIPE.

Internal Diameter, in.	Minimum Shell Thickness, in.	Test Requirements		
		Minimum Tensile Strength of Concrete in Shell of Pipe, lb. per sq. in.	Internal Hydrostatic Pressure on Individual Pipe, lb. per sq. in.	Maximum Head Under Which Properly Designed Pipe Lines Should be Operated, ft.
6	$\frac{5}{8}$	300	63	35
8	$\frac{3}{4}$	300	55	30
10	$\frac{7}{8}$	300	50	30
12	1	300	47	25
14	$1\frac{1}{8}$	300	45	25
15	$1\frac{1}{4}$	250	41	25
16	$1\frac{3}{8}$	250	39	20
18	$1\frac{1}{2}$	200	33	20
20	$1\frac{5}{8}$	200	35	20
21	$1\frac{3}{4}$	200	33	20
24	$2\frac{1}{8}$	200	37	20

Mixture

8. The aggregates shall be so graded and proportioned and thoroughly mixed with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the concrete will conform to the test and design requirements of these specifications.

DESIGN

Minimum Designs

9. The shell thickness shall not be less than the minimum design requirements given in Table I for sizes of pipe and the strength of concrete therein specified.

Joints

10. The ends of concrete irrigation pipe shall be so formed that when the pipe are laid together and the joints cemented they will make a continuous and uniform line of pipe with a smooth and regular interior surface. The joint shall be of such design as will permit effective cementing and placement without appreciable irregularities in the flow line.

PHYSICAL TEST REQUIREMENTS

Tensile Strength

11. The tensile strength of the concrete in the shell of concrete irrigation pipe shall conform to the requirements given in Table I.

Hydrostatic Test

12. When individual pipe is subjected to the internal hydrostatic pressures given in Table I, there shall be no leakage through the shell of the pipe. Moisture appearing on the surface of the pipe in the form of patches or beads adhering to the surface shall not be considered leakage.

PHYSICAL TESTS

Test Specimens

13. The specimens for the tensile strength and hydrostatic test shall be full size pipe which shall in every respect conform to the inspection requirements specified in Section 22.

Selection of Specimens for Tests

14. The specimens to be tested shall be representative and shall be selected by the purchaser or his representative at the point or points designated by him when placing the order. The manufacturer shall furnish for testing purposes and at his own expense, one specimen for every 1000 ft. of each size included in the order; the manufacturer bearing all expense of testing such pipe. Should additional tests be made upon demand of the purchaser or manufacturer, then the cost of such additional test specimens and the expense of testing shall be borne by the party making such demand.

Complying with Strength Tests

15. (*a*) Should the test specimens selected by the purchaser conform to the test requirements in Table I, then all pipe represented by such specimens shall be accepted as to strength, provided the pipe shall otherwise conform to the specifications.

(*b*) Should any of the specimens first tested fail to conform to the test requirements, then the manufacturer shall have the right to test three additional lengths of pipe from the same lot for each specimen that has failed. If the additional pipe so tested all conform to the test requirements, then all pipe represented by such tests shall be accepted; otherwise they shall be rejected, unless other tests, mutually agreed upon between the purchaser and manufacturer, demonstrate to the satisfaction of the purchaser, the acceptability of the pipe.

HYDROSTATIC TEST

Hydrostatic Test for Tensile Strength

16. The tensile strength of the concrete in concrete irrigation pipe shall be determined by any method in which the ends of the pipe are tightly closed in such a way that no longitudinal stresses are produced in the pipe shell. Suitable fittings shall be provided for exhausting the air and admitting the water into the specimen. A standardized pressure gage for recording the internal pressure shall be connected close to the specimen. The water pressure shall be applied uniformly until the required pressure is reached. The specimen shall not be required to stand under hydrostatic pressure longer than is required to observe and record the pressure, and to meet the test requirements.

Calculation of Tensile Strength

17. Tensile strength of the concrete in the shell of the pipe shall be calculated from the internal hydrostatic pressure shown in hydrostatic tests by use of the following formula:

$$\text{T. S.} = \frac{P \times r}{t}$$

where T. S. = the tensile strength of the concrete in the shell of the pipe, in pounds per square inch

P = the internal hydrostatic pressure in pounds per square inch as shown by a standard pressure gage

r = the radius (one-half the internal diameter) of the pipe in inches

t = the average thickness of the shell of the pipe in inches.

SIZE AND PERMISSIBLE VARIATIONS

Standard Sizes

18. Pipe of the internal diameters listed in Table I shall be considered standard sizes.

Variation in Dimensions

19. Variation of the internal diameter shall not exceed ± $\frac{1}{4}$ in. on pipe up to and including 18 in. in diameter, and ± $\frac{3}{8}$ in. on pipe 20 in. and up to and including 24 in. in diameter.

WORKMANSHIP AND FINISH

Finish

20. Pipe shall be free from fractures, cracks and surface roughness, other than those normally produced in the manufacture of the pipe. The planes of the ends of the pipe shall be perpendicular to their longitudinal axes.

INSPECTION AND REJECTION

Maximum Age for Shipment

21. Pipe shall be considered ready for shipment when they conform to the test requirements.

Causes for Rejection

22. Pipe shall be subject to rejection on account of failure to conform to any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell.

(*b*) Defects which indicate imperfect mixing, placing or curing of the concrete.

AMERICAN ASSOCIATION STATE
HIGHWAY OFFICIALS STANDARD
A.A.S.H.O.S. No.: M-41 AND T-33

TENTATIVE SPECIFICATIONS
FOR
REINFORCED-CONCRETE CULVERT PIPE[1]

A.S.T.M. Designation: C 76 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1930; Revised, 1935.

Scope

1. These specifications cover reinforced-concrete pipe intended to be used for the construction of culverts.

Classes

2. Pipe manufactured according to these specifications shall be of two classes known respectively as "Standard-Strength Reinforced-Concrete Culvert Pipe" and "Extra-Strength Reinforced-Concrete Culvert Pipe."

Basis of Acceptance

3. The acceptability of pipe shall be determined by the results of the strength and absorption tests specified herein, if and when required, and by inspection to determine whether the pipe conforms to the specifications in design and freedom from defects.

Materials

Reinforced Concrete

4. The reinforced concrete shall consist of portland cement, mineral aggregate, and water, in which steel has been embedded in such a manner that the steel and the concrete act together.

Cement

5. Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9),[2] or Tentative Specifications for High-Early-Strength Portland Cement (A.S.T.M. Designation: C 74 – 30 T),[3] of the American Society for Testing Materials.

Steel

6. Reinforcement may consist either of wire which conforms to the requirements of the Standard Specifications for Cold-Drawn Steel Wire

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee C-13 on Concrete Pipe.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 3.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 1016 (1930); also 1935 Book of A.S.T.M. Tentative Standards, p. 412.

for Concrete Reinforcement (A.S.T.M. Designation: A 82),[1] or of bars of structural or intermediate grade which conform to the requirements of the Standard Specifications for Billet-Steel Concrete-Reinforcement Bars, structural or intermediate grade (A.S.T.M. Designation: A 15),[2] of the American Society for Testing Materials.

Aggregates

7. Aggregates shall conform to the requirements of the Tentative Specifications for Concrete Aggregates (A.S.T.M. Designation: C 33-31 T) of the American Society for Testing Materials.[3]

Mixture

8. The aggregates shall be so graded and proportioned and thoroughly mixed in a batch mixer with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of these specifications. In no case, however, shall the proportion of Portland cement in the mixture be less than six U. S. standard bags (94 lb.) per cubic yard of concrete.

Placing Reinforcement

9. In circular pipe having one line of circular reinforcement, the reinforcement shall be placed equally distant from the inner and outer surfaces of the pipe. In circular pipe having two lines of circular reinforcement, each line shall be so placed that the net protective covering of concrete over the reinforcement shall be 1 in. In circular pipe having elliptical reinforcement, and in elliptical pipe having circular reinforcement, the reinforcement shall be so placed that the net protective covering of concrete along the vertical diameter of the pipe shall be 1 in. from the inside surface of the pipe, and the net protective covering of concrete along the horizontal diameter of the pipe shall be 1 in. from the outside surface of the pipe. (See Section 31 (*d*)). The location of the reinforcement shall be subject, however, to the tolerance permitted in Section 29 (*b*).

Design

Minimum Designs

10. The shell thickness and the amount of circumferential reinforcement shall not be less than that given in Tables I and II for the classes and sizes of pipe therein specified.

Alternative Designs

11. Manufacturers may submit to the purchaser, for approval, designs other than those given in Tables I and II, provided that such pipe shall meet the same physical tests and inspection requirements as herein prescribed for the pipe for which it is substituted. In no alternative design, however, shall the shell thickness be less than given in the tables.

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 23.

[2] 1935 Supplement to Book of A.S.T.M. Standards, p. 1.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 750 (1931); also 1935 Book of A.S.T.M. Tentative Standards, p. 578.

Joints

12. The ends of the pipe shall be of such design that the pipe when laid shall form a continuous conduit with a smooth and uniform interior surface.

Longitudinals

13. Each line of circumferential reinforcement shall be assembled into a cage which shall contain sufficient longitudinal bars or members, extending through the barrel of the pipe, to maintain the reinforcement rigidly in exact shape and correct position within the form.

TABLE I.—STANDARD-STRENGTH REINFORCED-CONCRETE CULVERT PIPE.

Internal Diameter of Pipe, in.	Concrete, 3500 lb. per sq. in.			Concrete, 4500 lb. per sq. in.			Strength Test Requirements, lb. per linear ft. of pipe	
	Minimum Shell Thickness, in.	Minimum Reinforcement, sq. in. per linear ft. of pipe		Minimum Shell Thickness, in.	Minimum Reinforcement, sq. in. per linear ft. of pipe		Three-Edge Bearing[a]	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Load to Produce a 0.01-in. Crack	Ultimate Load
12........	2	1 line 0.07	.....	$1\frac{3}{4}$	1 line 0.08	.....	2250	3 500
15........	$2\frac{1}{4}$	1 line 0.09	.....	2	1 line 0.11	.....	2625	4 065
18........	$2\frac{1}{2}$	1 line 0.12	1 line 0.10	$2\frac{1}{4}$	1 line 0.14	.....	3000	4 500
24........	3	1 line 0.17	1 line 0.13	$2\frac{5}{8}$	1 line 0.20	1 line 0.17	3000	5 000
30........	$3\frac{1}{2}$	2 lines, each 0.17	1 line 0.17	3	1 line 0.28	1 line 0.21	3375	5 750
36........	4	2 lines, each 0.18	1 line 0.18	$3\frac{3}{8}$	2 lines, each 0.22	1 line 0.22	4050	6 600
42........	$4\frac{1}{2}$	2 lines, each 0.21	1 line 0.21	$3\frac{3}{4}$	2 lines, each 0.25	1 line 0.25	4725	7 350
48........	5	2 lines, each 0.25	1 line 0.25	$4\frac{1}{4}$	2 lines, each 0.31	1 line 0.31	5400	8 000
54........	$5\frac{1}{2}$	2 lines, each 0.30	1 line 0.30	$4\frac{5}{8}$	2 lines, each 0.37	1 line 0.37	5850	9 000
60........	6	2 lines, each 0.33	1 line 0.33	5	2 lines, each 0.41	1 line 0.41	6000	10 000
72........	7	2 lines, each 0.40	1 line 0.40	6	2 lines, each 0.48	1 line 0.48	6600	12 000
84........	8	2 lines, each 0.46	1 line 0.46	7	2 lines, each 0.54	1 line 0.54	7000	14 000

[a] Test loads for sand-bearing tests shall be one and one-half times those specified in this table for the three-edge-bearing tests.

Laps, Welds, and Spacing

14. If the splices are not welded, the reinforcement shall be lapped not less than 30 diameters for bars, and 40 diameters for cold-drawn wire. If welded, the splices and intersections shall develop a tensile strength not less than the minimum strength required for the reinforcement by the applicable specifications cited in Section 6. The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. for pipe up to and including 48 in. in diameter, and shall not exceed the shell thickness for larger pipe, and shall in no case exceed 6 in.

Joint Reinforcement

15. The joint shall have a circumferential reinforcement equal in unit area to that of a single line within the barrel of the pipe.

CURING

16. Pipe shall be subjected to any one of the methods of curing described in the following Paragraphs (*a*) to (*c*) or to any other method, approved by the purchaser, that will give satisfactory results:

Steam Curing

(*a*) Pipe may be placed in a curing chamber, free from outside drafts, where the pipe shall be subjected to the action of thoroughly saturated steam at a temperature between 100 and 130 F. (38 and 54 C.) for a period of not less than 36 hr. or, when necessary, for such additional time as may be needed to enable the pipe to meet the strength requirements (Note). When a curing chamber is not available, pipe may be placed in an enclosure of canvas or other closely woven material and subjected to saturated steam at the temperature and for the time specified above. The enclosure shall be so erected as to allow full circulation of steam around the entire pipe. The interior surfaces of the curing room or canvas jackets and the surfaces of the pipe shall be entirely moist at all times.

TABLE II.—EXTRA-STRENGTH REINFORCED-CONCRETE CULVERT PIPE.

Internal Diameter of Pipe, in.	Concrete, 4500 lb. per sq. in.			Strength Test Requirements, lb. per linear ft. of pipe	
	Minimum Shell Thickness, in.	Minimum Reinforcement, sq. in. per linear ft. of pipe		Three-Edge Bearing[a]	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Load to Produce a 0.01-in. Crack	Ultimate Load
24	3	1 line 0.26	1 line 0.20	4 000	6 000
30	3½	2 lines, each 0.24	1 line 0.24	5 000	7 500
36	4	2 lines, each 0.28	1 line 0.28	6 000	9 000
42	4½	2 lines, each 0.33	1 line 0.33	7 000	10 500
48	5	2 lines, each 0.38	1 line 0.38	8 000	12 000
54	5½	2 lines, each 0.44	1 line 0.44	9 000	13 500
60	6	2 lines, each 0.50	1 line 0.50	9 000	15 000
72	7	2 lines, each 0.60	1 line 0.60	9 900	18 000
84	8	2 lines, each 0.72	1 line 0.72	10 500	21 000

[a] Test loads for sand-bearing tests shall be one and one-half times those specified in this table for the three-edge-bearing tests.

Water Spray Curing

(*b*) Under the conditions of enclosure prescribed in Paragraph (*a*), pipe may be cured by subjecting it to a continuous or frequently-applied fine spray of water in an enclosure maintained at a temperature of not less than 70 F. (21 C.) for a period of not less than 72 hr., or such additional time as may be necessary to meet the strength requirements (Note). If the enclosure is maintained at a temperature of less than 70 F. (21 C.), the curing period shall be increased as may be necessary to meet the strength requirements.

Saturated Cover Curing

(*c*) The sides and top of each pipe may be covered with heavy burlap, or other suitable material, saturated with water before applying and kept saturated with water at a temperature of not less than 70 F. (21 C.) for 72 hr., or such additional time as may be necessary to meet the strength requirements (Note). The ends of the pipe shall be so enclosed as to prevent the free circulation of air through or around the pipe. If the temperature of the water is less than 70 F. (21 C.), the curing period shall be increased as may be necessary to meet the strength requirements.

NOTE.—When high-early-strength Portland cement is used the time of curing specified for each of the methods prescribed in Paragraphs (*a*) to (*c*) may be reduced to 24 hr., or such additional time as may be necessary to meet the requirements of the purchaser.

PHYSICAL TEST REQUIREMENTS

Strength Requirements

17. The ultimate load, as determined by either of the methods described in Section 20, shall be not less than the ultimate load specified in Tables I and II. When the test load reaches the cracking load given in the tables, for the size and class of pipe tested, there shall be in the barrel of the pipe no crack having a width of 0.01 in. or more for a length of 1 ft. or more. The crack shall be considered 0.01 in. in width when the point of the measuring gage will penetrate it $\frac{1}{16}$ in. at close intervals throughout the specified distance of 1 ft. The width of crack shall be measured by means of a gage made from a leaf 0.01 in. in thickness (as in a set of standard machinist's gages), ground to a point $\frac{1}{16}$ in. in width, with corners rounded, and a taper of $\frac{1}{4}$ in. per inch, as illustrated in Fig. 1. The ultimate load is reached when the pipe will sustain no greater load.

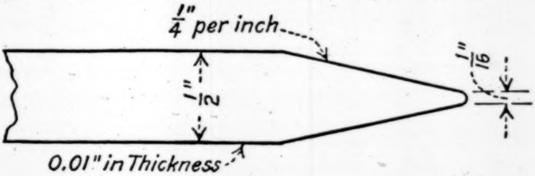


FIG. 1.—Gage Leaf for Measuring Cracks.

Elliptical Pipe

18. Elliptical pipe shall conform to the test requirements for circular pipe having the same horizontal internal diameter.

Test Requirements and Acceptability Under Absorption Tests

19. The absorption, determined as specified in Section 26, shall not exceed 8 per cent of the dry weight. Pipe shall be considered as conforming to these specifications for absorption when not less than 80 per cent of the number of specimens tested, including any retested, conform to the test requirements. When the initial absorption specimen from a pipe fails to conform to these specifications, the absorption test shall be made on another specimen from the same pipe and the results of the retest shall be substituted for the original test results.

PHYSICAL TESTS

Strength Tests

Strength Tests

20. Pipe may be tested for strength by either the three-edge-bearing or sand-bearing method, as described in the following Paragraphs (*a*) to (*c*):

Three-Edge-Bearing Method

(*a*) When the three-edge-bearing method is used, the lower bearing for the pipe shall consist of two wooden strips with vertical sides, having their interior top corners rounded to a radius of approximately $\frac{1}{2}$ in. The strips shall be straight and shall be securely fastened to a rigid base with the interior vertical sides parallel and spaced a distance apart of 1 in. per foot of pipe diameter, but in no case less than 1 in. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive of bell. The pipe shall be placed symmetrically between the two bearings as illustrated in Figs. 2 and 3. In testing pipe which is "out of line" the lines of the bearings chosen shall be those which appear to give the most favorable conditions for fair test.

Sand-Bearing Method

(*b*) When the sand-bearing method is used (see Figs. 4 and 5) the ends of each specimen of pipe shall be accurately marked prior to the test, in quarters of the circumference. Specimens shall be carefully bedded in sand, above and below, for one-fourth the circumference of the pipe, measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean and shall contain not less than 5 per cent of moisture, and shall be such as will pass a 4760-micron (No. 4) sieve. The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come into contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck off level with a straight edge, and shall be covered with a rigid top-bearing plate having its lower surface in a true plane, made of heavy timbers or other rigid material and capable of distributing the test load uniformly and without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate; provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may be attached, if desired, to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

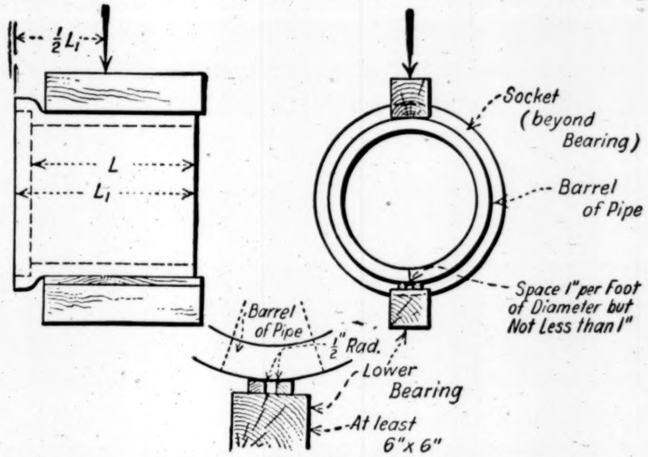

$\frac{1}{2}L_1$
L
L_1
Socket (beyond Bearing)
Barrel of Pipe
Space 1" per Foot of Diameter but Not Less than 1"
Barrel of Pipe
$\frac{1}{2}$" Rad.
Lower Bearing
At least 6" x 6"

FIG. 2.—Three-Edge Bearings.

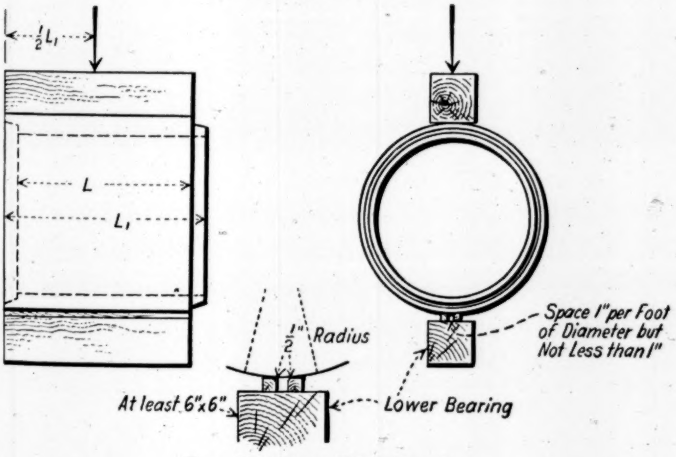

$\frac{1}{2}L_1$
L
L_1
$\frac{1}{2}$" Radius
Space 1" per Foot of Diameter but Not Less than 1"
At least 6" x 6"
Lower Bearing

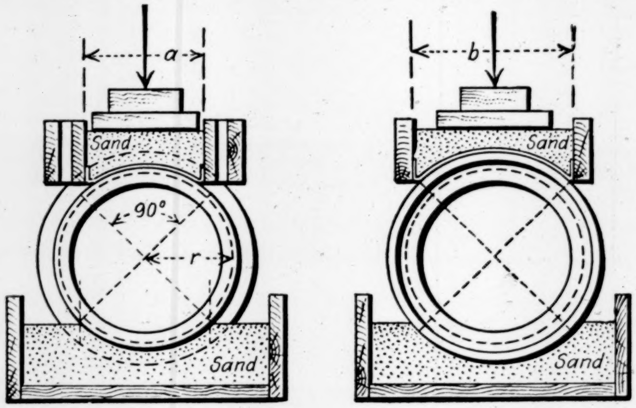
FIG. 3.—Three-Edge Bearings.

Testing Apparatus

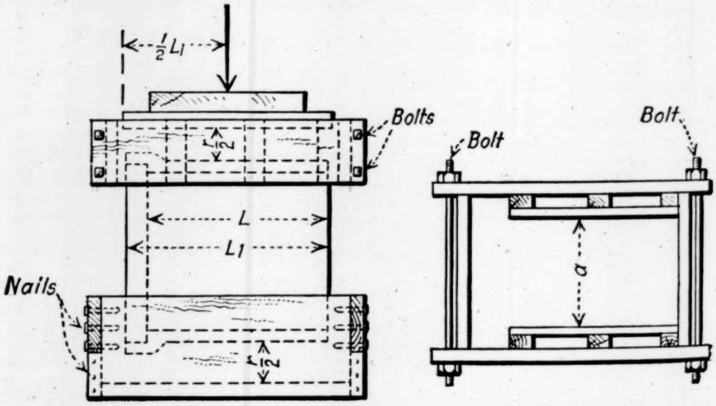
(*c*) It is desirable that the testing machine used for the strength tests shall produce a uniform deflection throughout the full length of the pipe. Any mechanical or hand-power device may be used in which the head that applies the load moves at a speed of not more than 0.05 in. per min. while making the test. The testing machine shall be substantial and rigid throughout; so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the ultimate strength of the pipe is reached.

Preliminary Tests and Tests for Extended Deliveries

21. A purchaser of pipe whose needs require shipments at intervals over extended periods of time, shall be entitled to preliminary tests of not more than three pieces of pipe covering each size in which he is interested. The acceptability of the larger sizes of the pipe shall not be based on the results of tests of smaller sizes. After these preliminary tests, a purchaser shall be entitled to additional tests in such numbers and at such times as he may deem necessary, provided that the total number of pipe tested shall not exceed 2 per cent of the deliveries.



Bedding of Barrel. Bedding of Socket.



Side View. Upper Bearing Frame.

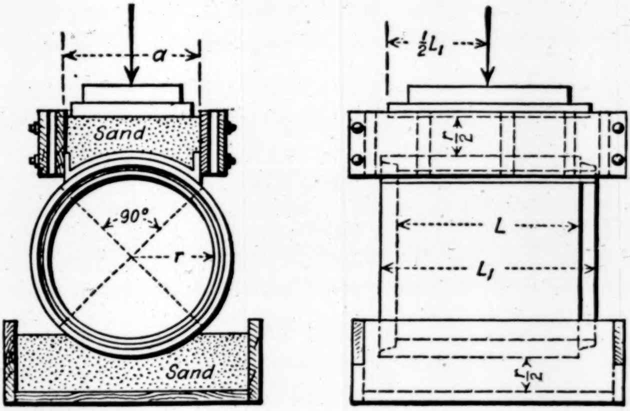
FIG. 4.—Sand Bearings.

Tests for Occasional Orders

22. A purchaser who places occasional orders shall be entitled to test a number of pipe not to exceed 2 per cent of an order, and not to exceed five pieces of any one size; otherwise the number of pipe desired for testing shall be included in the order.

Selecting Test Specimens

23. The specified number of pipe for purpose of tests shall be furnished without charge by the manufacturer and shall be selected at random by the purchaser, and shall be pipe which would not otherwise be rejected under these specifications. The pipe shall be surface-dry when tested and shall not have been exposed to a temperature below 40 F. (5 C.) for the 24 hr. immediately preceding the test.



Bedding of Barrel.

FIG. 5.—Sand Bearings.

Acceptability and Retests

24. Pipe shall be acceptable under the strength tests when all test specimens conform to the test requirements. Should any of the preliminary test specimens provided for in Section 21, or any of the test specimens provided for in Section 22, fail to meet the test requirements, then the manufacturer will be allowed a retest on two additional specimens for each specimen that failed, and the pipe shall be acceptable only when all of these retest specimens meet the strength requirements.

Concrete Tests and Reinforcement Examinations

25. By agreement between the purchaser and manufacturer, the continued acceptability of the pipe (after the preliminary pipe tests have been made), may be determined by tests of the quality of the concrete as

placed in the pipe, and examination of the quality, amount, and accuracy of placement of reinforcement. If the quality of the concrete is determined from 6 by 12-in. test cylinders, they shall be made from the concrete used in making the pipe and shall be manufactured and cured under identical conditions with the pipe. Such cylinders shall be tested in accordance with the Standard Methods of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39) of the American Society for Testing Materials.[1]

Absorption Test

26. Absorption tests shall be made in accordance with the procedure described in the following Paragraphs (*a*) to (*e*):

Test Specimens

(*a*) The number of absorption test specimens shall be equal to the number of pipe provided for testing. The specimens shall be obtained from pipe that are acceptable as to strength, and shall be taken from pipe used in making the strength test after that test is made. The specimens shall be marked with the number or identification mark of the pipe from which they were taken. Each specimen shall have an area of 16 to 24 sq. in., as measured on one surface of the pipe, and a thickness equal to the full depth of the pipe shell, and shall be free from visible cracks.

Drying Specimens

(*b*) Specimens shall be dried at a temperature not to exceed approximately 230 F. (110 C.) until two successive weighings at intervals of not less than 2 hr. show an increment of loss not greater than 0.1 per cent of the original weight of the specimen.

Immersion and Reweighing

(*c*) The dried specimens shall be placed in a suitable receptacle, covered with distilled water or rain water, raised to the boiling point and boiled for 5 hr., and then cooled in water to a final temperature of from 59 to 68 F. (15 to 20 C.). When cool, the specimens shall be removed from the water and allowed to drain for not more than 1 min. The superficial water shall then be removed by a towel or blotting paper, and the specimens immediately weighed.

Weighing Devices

(*d*) The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same degree of accuracy shall be obtained.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 230.

Calculation and Reporting of Results

(*e*) The increase in weight of the boiled specimen over its dry weight shall be taken as the absorption of the specimen, and shall be expressed as a percentage of the dry weight. The results shall be reported separately for each specimen.

Test Equipment

27. Every manufacturer furnishing pipe under these specifications shall furnish all facilities necessary to carry out the tests required in these specifications.

SIZE AND PERMISSIBLE VARIATIONS

Standard Sizes

28. Pipe of the internal diameters listed in Tables I and II shall be the standard sizes for culvert construction. In elliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

Variations in Dimensions

29. (*a*) Variations of the internal diameter shall not exceed ±1 per cent for pipe having an internal diameter of 36 in. or less, and shall not exceed ±0.75 per cent for larger pipe. The shell thickness shall not be less than that intended in the design, by more than 5 per cent at any point.

(*b*) Variations of the position of the reinforcement shall not exceed $\frac{1}{4}$ in. from the position provided in the design for pipe having an internal diameter of 48 in. or less, and shall not exceed $\frac{1}{2}$ in. for larger pipe; but the cover on the reinforcement shall not be less than $\frac{3}{4}$ in. at any point.

WORKMANSHIP AND FINISH

Finish

30. Pipe shall be substantially free from fractures, large or deep cracks and surface roughness. The planes of the ends of the pipe shall be perpendicular to the longitudinal axis.

MARKING

Marking

31. The following shall be clearly stenciled on the pipe:

(*a*) The pipe class $\left\{\begin{array}{l}\text{by an “S-C” for Standard-Strength Pipe, and}\\ \text{by an “X-C” for Extra-Strength Pipe;}\end{array}\right.$

(*b*) The date of manufacture;

(*c*) The name or trade-mark of the manufacturer, and

(*d*) Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the word “Top” or “Bottom” clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

INSPECTION AND REJECTION

Minimum Age for Shipment

32. Pipe shall be considered ready for shipment when they conform to the requirements, as indicated by the specified tests.

Inspection

33. All materials, processes of manufacture and finished pipe shall be subject to inspection and approval by an inspector employed by the purchaser. The manufacturer, when so directed by the inspector, shall have holes cut in such sections of the finished pipe (not exceeding one hole in every 50 sections delivered), as desired, so that a proper inspection may be made of the quantity and placement of the reinforcement. If the pipe is also tested for strength or absorption, inspection of the reinforcement shall be made on the pipe sections used for those tests, and in no case shall the total number of pipe cut open for inspection of reinforcement exceed the number to which the purchaser is entitled under the provisions of Section 21 or 22.

Causes for Rejection of Pipe

34. Pipe shall be subject to rejection on account of failure to meet any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell, except that a single end-crack that does not exceed the depth of the joint shall not be cause for rejection. If a single end-crack that does not exceed the depth of the joint exists in more than ten per cent of the pipe inspected, however, the defective pipe shall be rejected.

(*b*) Defects which indicate imperfect mixing and molding.

(*c*) Surface defects indicating honeycombed or open texture.

(*d*) Spalls deeper than one-half the depth of the joint or extending more than 4 in. around the circumference. If spalls not deeper than one-half the depth of the joint or extending not more than 4 in. around the circumference exist in more than 10 per cent of the pipe, however, the defective pipe shall be rejected.

(*e*) Exposure of the reinforcement when such exposure would indicate that the reinforcement is misplaced.

TENTATIVE DEFINITIONS OF TERMS RELATING TO CLAY SEWER PIPE[1]

A.S.T.M. Designation: C 8 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Forces Acting Upon Sewer Pipe

External Forces.—Forces resulting from pressures or impact acting from the outside upon the pipe.

Internal Forces.—Forces resulting from interior fluid pressure.

Abrasion.—Wearing away of surface material by friction.

Raw Materials

Clay.—An earthy or stony mineral aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry, and vitreous when fired at a sufficiently high temperature.

Surface Clay.—An unconsolidated, unstratified clay, occurring on the surface.

Fire Clay.—A sedimentary clay of low flux content.

Note.—It is usually associated with coal measures.

Shale.—A thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.

Pipe

Sewer Pipe.—Separate pipe suitable for the conveyance of domestic and industrial sewage and storm water, and capable of being joined to form a conduit.

Fittings.—A pipe other than a straight pipe.

Fittings or Branches.—A pipe attached to and diverging from the barrel of another pipe, such as Y-branches, T-branches, etc.

Demands upon Sewer Pipes.—Requirements of qualities which are desirable and attainable under conditions of actual practice.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee C-4 on Clay Pipe.

These definitions are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Definitions of Terms Relating to Sewer Pipe (A.S.T.M. Designation: C 8 – 24), see 1933 Book of A.S.T.M. Standards, Part II, p. 218.

PARTS OF SEWER PIPE

Barrel.—Main body of a pipe, exclusive of differently formed ends.

Ends.—Those parts of a pipe which terminate it and are so formed as to permit of making a proper joint.

Socket.—That end of a pipe which is sufficiently enlarged for a short distance to receive and enclose the spigot end of the adjoining pipe to form a joint.

Spigot.—That end of a pipe which enters and is formed to fit the socket of the adjoining pipe; it is sometimes scored.

Base, Form of.—Shape of that part of a pipe which rests upon a foundation.

Annular Space.—The space extending around the periphery of a pipe between the inside of the socket and the outside of the spigot.

JOINTS

Spigot Joint.—Formed by inserting the spigot end of one pipe into the socket of another and applying the jointing material.

Jointing Materials.—The materials which are inserted in the annular space between the inside of the socket and the outside of the spigot and between the ends of adjoining pipes for the purpose of forming a continuous closed conduit.

Elasticity of Joints.—Ability of jointed pipes to resist strains caused by bending and returning to original position.

FINISHED PRODUCT

(*a*) *Material*

Durability.—Resistance to disintegration or deterioration.

Serviceability.—Ability to readily and effectively render satisfactory service.

Thickness.—Distance between outside and inside surfaces.

Strength.—Ability to resist physical forces imposed during handling and after pipe has been put in use.

Smoothness.—Evenness of surface without projections or irregularities.

(*b*) *Covering*

Glazing.—Hard glassy surface covering.

Salt Glazing.—Glazing produced by injection of salt into kilns at time of maturing temperature.

(*c*) *Defects*

Warp.—Twisted out of normal shape.

Fracture.—Rupture of the material by a break through its entire thickness.

Crack.—Fissure or open seam not necessarily extending through body of material.

Fire Crack.—A crack resulting from lack of uniformity in shrinkage after the application of excessive heat.

Hair Crack.—Irregularly running, fine, narrow crevice or fissure at the surface of a pipe not penetrating deeply, and caused by a shrinkage of material during manufacture.

Blister.—Convex hollow prominence formed by separation and raising of a film in the process of burning.

Lamination.—A stratification of the material in the plane of the wall of the pipe.

IDENTIFICATION

Marking and Imprints.—Impressions made upon pipe at the place and time of manufacture for the purpose of identification.

TENTATIVE METHOD OF TEST
FOR
DETERMINATION OF AMOUNT OF MATERIAL FINER THAN No. 200 SIEVE IN AGGREGATES[1]

A.S.T.M. Designation: C 117 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method of test outlines the procedure for determining the total quantity of material finer than a standard No. 200 (74-micron) A.S.T.M. sieve in aggregates. (See Explanatory Note.)

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Sieves.*—A nest of two sieves, the first being a No. 200 (74-micron) sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials,[2] and the second, a sieve having approximately 16 meshes per linear inch.

(*b*) *Container.*—A pan or vessel of a size sufficient to contain the sample covered with water and to permit of vigorous agitation without inadvertent loss of any part of the sample or water.

Test Sample

3. (*a*) The test sample shall be selected from material which has been thoroughly mixed and which contains sufficient moisture to prevent segregation. A representative sample, sufficient to yield not less than the appropriate weight of dried material, as shown in the following table, shall be selected:

NOMINAL DIAMETER OF LARGEST PARTICLE, IN.	APPROXIMATE MINIMUM WEIGHT OF SAMPLE, KG.
¼	0.5
¾	2.5
1½ or over	5.0

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[1] Under the standardization procedure of the Society, this method is under the joint jurisdiction of A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials.

This method is in effect a tentative revision of, and is intended to supersede when adopted as standard, the present Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 - 21), and Standard Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 28), see 1933 Book of A.S.T.M. Standards, Part II, pp. 950 and 951, respectively.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

Procedure

4. (*a*) The test sample shall be dried to constant weight at a temperature not exceeding 110 C. (230 F.) and weighed to the nearest 0.02 per cent.

(*b*) The test sample after being dried and weighed shall be placed in the container and sufficient water added to cover it. The contents of the container shall be agitated vigorously and the wash water poured immediately over the nested sieves, arranged with the coarser sieve on top.

(*c*) The agitation should be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the No. 200 (74-micron) A.S.T.M. sieve and bring the fine material into suspension in order that it will be removed by decantation of the wash water. Care shall be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

(*d*) All material retained on the nested sieves shall be returned to the washed sample. The washed aggregate shall be dried to constant weight at a temperature not exceeding 110 C. (230 F.) and weighed to the nearest 0.02 per cent.

Calculation of Results

5. The results shall be calculated from the following formula:

$$\text{Percentage of material finer than No. 200 (74-micron) A.S.T.M. sieve} = \frac{\text{Original dry weight} - \text{dry weight after washing}}{\text{Original dry weight}} \times 100$$

Check Determinations

6. When check determinations are desired, the wash water shall be either evaporated to dryness or filtered through tared filter paper which shall subsequently be dried, the residue weighed and the percentage calculated from the following formula:

$$\text{Percentage of material finer than No. 200 (74-micron) A.S.T.M. sieve} = \frac{\text{Weight of residue}}{\text{Original dry weight}} \times 100$$

EXPLANATORY NOTE

NOTE.—This tentative method was prepared by a joint Conference Committee on Silt and Loam, representing Committee C-9 on Concrete and Concrete Aggregates and Committee D-4 on Road and Paving Materials, as a replacement of the existing Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 21) and Method of Decantation Test for Sand and Other Fine Aggregates (D 136 – 28) for the following reasons:

1. To eliminate two existing standard methods which essentially are for the same purpose but which differ somewhat in technique and which may not give comparable results.

2. To define with precision the maximum size of the fine material determined by the test and thus eliminate such indefinite terms as clay, silt and loam.

3. To eliminate the sedimentation methods of the two existing standards. To secure accurate results by means of sedimentation it is necessary to control several variables which are not controlled in either of the existing standards. The control necessary for an accurate sedimentation test is a refinement which is not warranted by the purpose of these tests. The desired results may be secured by the simple washing test described in the proposed tentative method.

Attention should be called to the fact that the proposed method will not necessarily give results comparable with those obtained with either of the existing standard methods. The differences will depend on the grading and amount of the fine material and on the variations in the technique which are possible in conducting the tests in accordance with the present standard methods. Generally speaking, the new method may be expected to show somewhat higher percentages of fine material than the present standards and the replacement of these by the proposed method may require some revision in the test limits of existing standard specifications.

A number of tests made in one laboratory on representative sands for portland-cement concrete gave, with the proposed method, percentages of material finer than the No. 200 (74-micron) sieve which averaged about 0.3 per cent higher than the fine material determined by the present standard decantation test.

While it appears that relatively few commercial sands as now produced would be affected by the proposed change in the test method, recognition of the increased loss should probably be made in specification requirements to avoid the exclusion of what are, at present, border-line materials. For example, the usual limit for concrete sand of 3.0 per cent removed by decantation might be changed to 3.5 per cent of material finer than the No. 200 (74-micron) sieve, or to some other value which might be established by further tests.

TENTATIVE METHOD

OF

MAKING COMPRESSION TESTS OF CONCRETE USING PORTIONS OF BEAMS BROKEN IN FLEXURE[1]

(MODIFIED CUBE METHOD)

A.S.T.M. Designation: C 116 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Scope

1. This method is intended to cover compression tests of concrete using for the test specimens portions of beams broken in flexure in accordance with the Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading (A.S.T.M. Designation: C 78 - 30 T) of the American Society for Testing Materials,[2] or portions of beams having a square cross-section molded and tested in accordance with other recognized methods.

Size and Shape of Specimen

2. The broken portions of beams selected for the compression test shall have a length not less than 2 in. greater than the depth of the beam, and they shall be free from cracks, chipped surfaces, or other obvious defects.

Preparation of Test Specimen

3. If the sides of the beam as cast consist of plane, smooth surfaces accurate to 0.005 in., no capping will be necessary. If the sides of the beam as cast are not true planes they shall be capped in such a manner that plane surfaces are secured on opposite sides of the beam as cast. The caps shall cover the full width of the beam and shall be of such length as to permit the adjustment of the bearing plates for the test so that the upper bearing plate may be placed directly over the lower bearing plate. The material used for capping and the thickness of the cap shall be such that it will not flow under the load.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 1027 (1930); also 1935 Book of A.S.T.M. Tentative Standards, p. 597.

Method of Testing

4. Only the ultimate compressive strength shall be determined. The specimen shall be tested between machined metal bearing plates not less than $\frac{3}{4}$ in. in thickness. The diameter of the spherical bearing block shall be at least 75 per cent of the depth of the beam. The dimension of the plates parallel to the length of the beam shall be equal to the nominal depth of the beam. The upper bearing plate shall be placed directly over the lower plate. A device which insures the proper location of the upper plate with reference to the lower plate is shown in Fig. 1. The load shall be applied to the bearing blocks by means of an adjustable head.

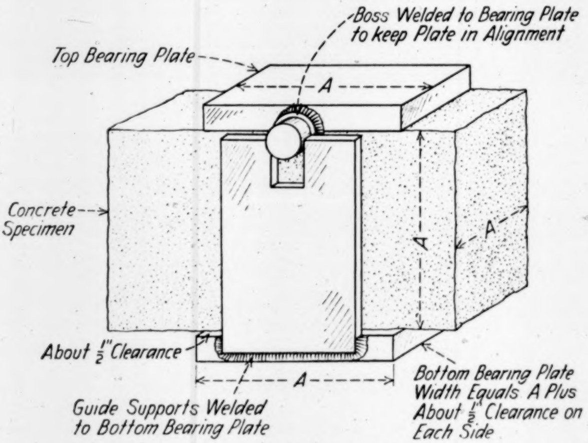
Boss Welded to Bearing Plate to keep Plate in Alignment
Top Bearing Plate
A
Concrete Specimen
A
A
About ½" Clearance
A
Guide Supports Welded to Bottom Bearing Plate
Bottom Bearing Plate Width Equals A Plus About ½" Clearance on Each Side

FIG. 1.—Device for Aligning Bearing Plates.

Application of Load

5. The load shall be applied uniformly and without shock. The rate of application of load shall be not in excess of that applied by a testing machine, the moving head of which under no load travels at the rate of 0.05 in. per min.

Record of Test

6. The total load indicated by the testing machine at failure of the test specimen shall be recorded and the unit compressive strength calculated in pounds per square inch. In calculating the unit compressive strength, the cross-sectional area shall be taken as the average of the upper and lower contact areas. The type of failure and appearance of the concrete shall be noted.

TENTATIVE METHOD OF TEST
FOR
SOUNDNESS OF COARSE AGGREGATES BY USE OF SODIUM SULFATE OR MAGNESIUM SULFATE[1]

A.S.T.M. Designation: C 89 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1931; REVISED, 1932, 1935.

Scope

1. This method describes the procedure to be followed in testing coarse aggregates to determine their soundness as indicated after immersion in a saturated solution of sodium sulfate or magnesium sulfate (Note).

NOTE.—This method of test for the soundness of coarse aggregates includes two testing procedures, one by the use of sodium sulfate and the other by the use of magnesium sulfate. Either or both of these methods may be used at the option of the user. Special attention, however, is called to the fact that the test results by the use of these two methods differ considerably and care must be exercised in fixing proper test limits in any specifications which may include requirements for these tests.

It is recommended that the results obtained with this test method shall be considered only as a guide in the selection of aggregates. It is not intended that the test shall be used as an arbitrary basis for rejection of the material without taking other factors into account; consideration should be given to the results obtained with the material when exposed to actual weathering conditions.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Solution.*—Supply of sodium sulfate or magnesium sulfate saturation solution prepared in accordance with Section 3 (*a*) or (*b*).

(*b*) *Sieves.*—A No. 4 sieve conforming to the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials,[2] and sieves with square openings in sizes $\frac{3}{8}$ in., $\frac{3}{4}$ in., $1\frac{1}{2}$ in., $2\frac{1}{2}$ in. and larger sizes by 1-in. spread for screening the samples in accordance with Sections 4 and 5.

(*c*) *Containers.*—Suitable containers (Note) for immersing the samples of aggregate in the solution in accordance with the procedure hereinafter described shall be selected. The containers shall be non-metallic or of metal not subject to corrosion by sodium sulfate or magnesium sulfate.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

NOTE.—No standard form of container is recommended since different practices will be most convenient in various laboratories, and the committee does not feel that this question, except for obvious fundamentals, is of importance. Two general methods of immersion have been used, as follows:

(*1*) Each sample placed in a water-tight container and covered with sodium sulfate or magnesium sulfate solution.

(*2*) Each sample placed in a perforated container and immersed in a vat containing the sodium sulfate or magnesium sulfate solution.

(*d*) *Temperature Regulation.*—Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate or magnesium sulfate solution shall be provided.

(*e*) *Balance.*—A balance having a capacity not less than 5000 g., sensitive to at least 1 g., shall be used.

(*f*) *Drying Oven.*—The drying oven shall provide a free circulation of air through the oven and shall be capable of maintaining a temperature of 105 to 110 C. (221 to 230 F.).

Sodium Sulfate Solution

3. (*a*) The sodium sulfate solution shall be saturated by dissolving the salt, either of the anhydrous (Na_2SO_4) or crystalline ($Na_2SO_4 \cdot 10\ H_2O$) form, in water at a temperature of 24 to 27 C. (75 to 80 F.). The solution shall be thoroughly stirred during the addition of the salt and sufficient excess salt shall be added to insure saturation. (About 500 g. of the anhydrous form or 1000 g. of the decahydrate will be required for each liter of water.) The solution shall be allowed to cool, before use, to a temperature of 21 C. ± 1 C. (70 F. ± 2 F.).

Magnesium Sulfate Solution

(*b*) The magnesium sulfate solution shall be saturated by dissolving the salt, either of the anhydrous ($MgSO_4$) or crystalline ($MgSO_4 \cdot 7\ H_2O$) (Epsom salt) form, in water at a temperature of 24 to 27 C. (75 to 80 F.). The solution shall be thoroughly stirred during the addition of the salt and sufficient excess salt shall be added to insure saturation. (About 325 g. of the anhydrous form or 650 g. of the crystalline form will be required for each liter of water). The solution shall be allowed to cool to room temperature before use, which shall not be lower than 20 C. (68 F.).

Samples of Coarse Aggregate

4. (*a*) Samples of coarse aggregrate for the test shall consist of material from which the sizes finer than the No. 4 sieve have been removed. The sample shall be of such a size that it will yield not less than the following amounts of the different sizes, which are available in amounts of 5 per cent or more.

No. 4 to $\frac{3}{8}$-in. size (square openings)	100 g.
$\frac{3}{8}$ to $\frac{3}{4}$-in. size (square openings)	300 g.
$\frac{3}{4}$ to $1\frac{1}{2}$-in. size (square openings)	1500 g.
$1\frac{1}{2}$ to $2\frac{1}{2}$-in. size (square openings)	3000 g.
Larger sizes by 1-in. spread in sieve size, each fraction	3000 g.

(*b*) Should the samples of coarse aggregate contain less than 5 per cent of any of the sizes specified in Paragraph (*a*), that size shall not be tested, but, for the purpose of calculating the test results, shall be considered to have the same loss in sodium sulfate or magnesium sulfate treatment as the average of the sizes tested.

Preparation of Test Sample

5. (*a*) The sample shall be thoroughly washed and dried to constant weight at a temperature of 105 to 110 C. (221 to 230 F.), and the samples of gravel or crushed stone shall be separated into different sizes by screening to refusal. The proper weight of sample for each fraction shall be weighed out and placed in separate containers for the test. In the case of fractions coarser than the $\frac{3}{4}$-in. sieve, the number of particles shall be counted.

(*b*) For testing ledge rock, the sample shall be prepared by breaking it into fragments reasonably uniform in size and shape and weighing approximately 100 g. each. The test sample shall weigh 5000 g. ± 2 per cent. The sample shall be thoroughly washed and dried previous to test as described in Paragraph (*a*).

Storage of Samples in Solution

6. The samples shall be immersed in the prepared solution of sodium sulfate or magnesium sulfate for 18 hr. in such a manner that the solution covers them to a depth of at least $\frac{1}{2}$ in. The containers shall be covered to reduce evaporation and prevent the accidental addition of extraneous substances. The samples immersed in the sodium-sulfate solution shall be maintained at a temperature (Note) of 21 C. ± 1 C. (70 F. ± 2 F.) for the 18-hr. period.

NOTE.—A moist room such as is used for curing concrete and mortar test specimens offers a convenient means of controlling the storage temperature. The presence of a few crystals of sodium sulfate or magnesium sulfate in the container is essential to keeping the solution saturated.

Attention is called to the fact that it is not necessary to control the temperature of the magnesium-sulfate solution, as the solubility of this salt is practically constant at laboratory temperatures between 20 to 30 C. (68 to 86 F.). However, it is necessary to keep a saturated solution which can be done by maintaining the specific gravity of the solution at not less than 1.29 at 25 C. (77 F.) as determined with a hydrometer.

Drying Samples After Immersion

7. After the 18-hr. immersion period the aggregate samples shall be removed from the solution and placed in the drying oven. The temperature of the oven shall have been brought previously to 105 to 110 C. (221 to 230 F.). Care shall be exercised to avoid loss of any aggregate particles (Note). The samples shall be dried to constant weight at the specified temperature. After drying, the samples shall be allowed to cool

to room temperature, when they shall again be immersed in the prepared solution as described in Section 6.

NOTE.—The detritus also should be saved if the complete analysis suggested in the Note in Section 11 (*b*) is made.

Cycles

8. The process of alternate immersion and drying shall be repeated until the required number of cycles is obtained.

Examination

9. Fractions of samples coarser than $\frac{3}{4}$ in. shall be examined qualitatively after each immersion and quantitatively at the completion of the test. Fractions finer than $\frac{3}{4}$ in. shall be examined quantitatively only, and after the completion of the test.

Qualitative Examination

10. The qualitative examination and record shall consist of two parts: (*1*) Observing the effect of action (Note) by the sodium-sulfate or magnesium-sulfate solution and the nature of the action, and (*2*) counting the number of particles affected.

NOTE.—Many types of action may be expected. In general they may be classified as disintegration, splitting, crumbling, cracking, flaking.

While only particles larger than the $\frac{3}{4}$-in. size are to be examined qualitatively it is recommended that examination of the smaller sizes be made in order to determine if there is any evidence of excessive splitting.

Quantitative Examination

11. The quantitative examination (Note) shall be made as follows:

(*a*) After the completion of the final cycle and after the sample has cooled, the sample shall be washed free from the sodium sulfate or magnesium sulfate as determined by the reaction of the wash water with barium chloride ($BaCl_2$).

(*b*) In the case of gravel or crushed stone after the sodium sulfate or magnesium sulfate has been removed, each fraction of the sample shall be dried to constant weight at 105 to 110 C. (221 to 230 F.), weighed and screened over the same sieve on which it was retained before the test. The weight of the material passing the sieve shall be determined and the weight recorded.

NOTE.—In addition to the procedure described in Paragraphs (*a*) and (*b*) the following is suggested as giving additional information of value:

After treating each separate fraction of sample as described in Paragraph (*b*) all sizes, including the detritus, shall be combined and a sieve analysis made using a complete set of sieves for the determination of the fineness modulus. The results of the sieve analysis shall be recorded as cumulative percentages retained on each sieve.

(*c*) In the case of ledge rock the loss in weight shall be determined by subtracting from the original weight of the sample the final weight of all fragments which have not broken into three or more pieces.

Report

12. The report shall include the following data (Note):

(*a*) *For gravel, crushed stone or slag:*

- (*1*) Weight of each fraction of sample before test.
- (*2*) Number of particles in each fraction of sample coarser than ¾ in. before test.
- (*3*) The number of pieces affected, in fractions coarser than ¾ in. only, classified as to number disintegrated, split, cracked, flaked, etc.
- (*4*) Material from each fraction of sample, finer than sieve on which fraction was retained before test, expressed as percentage by weight of fraction.
- (*5*) Weighted average calculated from the percentages of loss for each fraction, based on the grading of the sample as received or, in the case of ledge rock, as prepared by breaking into particles for the test.
- (*6*) Character of solution (sodium or magnesium sulfate).

(*b*) *For ledge rock:*

- (*1*) The percentage of loss calculated as described in Section 11 (*c*).
- (*2*) The number of pieces affected, classified as to number disintegrated, split, cracked, flaked, etc.
- (*3*) Character of solution (sodium or magnesium sulfate).

NOTE.—The following table, shown with test values inserted for purpose of illustration, is a suggested form for recording test data.

Chemical Used in Test........................Sodium Sulfate

Sieve Size		Grading of Original Sample, per cent	(a) Weight of Test Fractions Before Test, g.	(b) Percentage Passing Finer Sieve After Test (Actual per cent Loss)	(c) Weighted Average (Corrected per cent Loss)
Passing	Retained on				
2½ in.	1½ in.	20.0	3000[a]	4.8	0.96
1½ in.	¾ in.	45.0	1500[a]	8.0	3.60
¾ in.	⅜ in.	23.0	300[a]	9.6	2.20
⅜ in.	No. 4	12.0	100[a]	11.2	1.34
Totals		100.0	4900		8.10

[a] Minimum amounts; larger samples may be used.

TENTATIVE METHOD OF TEST
FOR
SOUNDNESS OF FINE AGGREGATES BY USE OF SODIUM SULFATE OR MAGNESIUM SULFATE[1]

A.S.T.M. Designation: C 88 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1931; REVISED, 1932, 1935.

Scope

1. This method describes the procedure to be followed in testing fine aggregates to determine their soundness as indicated after immersion in a saturated solution of sodium sulfate or magnesium sulfate.

NOTE.—This method of test for soundness of fine aggregates includes two testing procedures, one by the use of sodium sulfate and the other by the use of magnesium sulfate. Either or both of these procedures may be used, at the option of the user. Special attention, however, is called to the fact that the test results by the use of these two methods differ considerably and care must be exercised in fixing proper test limits in any specifications which may include requirements for these tests.

It is recommended that the results obtained with this test method shall be considered only as a guide in the selection of aggregates. It is not intended that the test shall be used as an arbitrary basis for rejection of the material without taking other factors into account; consideration should be given to the results obtained with the material when exposed to actual weathering conditions.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Solution.*—Supply of sodium-sulfate or magnesium-sulfate saturated solution prepared in accordance with Section 3 (*a*) or (*b*).

(*b*) *Sieves.*—A nest of sieves comprising sizes Nos. 100, 50, 30, 16, 8 and 4, conforming to the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials[2] and also a $\frac{3}{8}$-in. sieve for screening the samples as specified in Sections 4 and 5.

(*c*) *Containers.*—Suitable containers (Note) for immersing the samples of aggregate in the solution in accordance with the procedure hereinafter described shall be selected. Containers shall be non-metallic or of metal not subject to corrosion by sodium sulfate or magnesium sulfate.

NOTE.—No standard form of container is recommended since different practices will be most convenient in various laboratories, and the committee does not feel that this question, except for obvious fundamentals, is of importance. Two general methods of immersion have been used as follows:

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

(*1*) Each sample placed in a water-tight container and covered with the sodium sulfate or magnesium sulfate solution.

(*2*) Each sample placed in a container with a wire mesh bottom and immersed in a vat containing the sodium sulfate or magnesium sulfate solution. Care should be taken to prevent loss by flotation if uncovered containers are submerged. If nesting sieves are used precaution should be taken to prevent loss of material from one sieve to another.

(*d*) *Temperature Regulation.*—Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate or magnesium sulfate solution shall be provided.

(*e*) *Balance.*—A balance having a capacity not less than 500 g., sensitive to at least 0.1 g., shall be used.

(*f*) *Drying Oven.*—The drying oven shall provide a free circulation of air through the oven and shall be capable of maintaining a temperature of 105 to 110 C. (221 to 230 F.).

Sodium Sulfate Solution

3. (*a*) The sodium sulfate solution shall be saturated by dissolving the salt, either of the anhydrous (Na_2SO_4) or crystalline ($Na_2SO_4 \cdot 10\ H_2O$) form, in water at a temperature of 24 to 27 C. (75 to 80 F.). The solution shall be thoroughly stirred during the addition of the salt and sufficient excess salt shall be added to insure saturation (about 500 g. of the anhydrous form or 1000 g. of the decahydrate will be required for each liter of water). The solution shall be allowed to cool before use to a temperature of 21 C ±1 C. (70 F. ±2 F.).

Magnesium Sulfate Solution

(*b*) The magnesium sulfate solution shall be saturated by dissolving the salt, either of the anhydrous ($MgSO_4$) or crystalline ($MgSO_4 \cdot 7\ H_2O$) (Epsom salt) form, in water at a temperature of 24 to 27 C. (75 to 80 F.). The solution shall be thoroughly stirred during the addition of the salt and sufficient excess salt shall be added to insure saturation (about 325 g. of the anhydrous form or 650 g. of the crystalline form will be required for each liter of water). The solution shall be allowed to cool to room temperature before use, which shall not be lower than 20 C. (68 F.).

Sample of Fine Aggregate

4. (*a*) Fine aggregate for the test shall be passed through a $\frac{3}{8}$-in. sieve. The sample shall be of such size that it will yield not less than 100 g. of each of the following sizes, which are available in amounts of 5 per cent or more, expressed in terms of the following A.S.T.M. sieves:

Retained on Sieve No. 100, passing Sieve No. 50
Retained on Sieve No. 50, passing Sieve No. 30
Retained on Sieve No. 30, passing Sieve No. 16
Retained on Sieve No. 16, passing Sieve No. 8
Retained on Sieve No. 8, passing Sieve No. 4
Retained on Sieve No. 4, passing $\frac{3}{8}$-in. sieve

(*b*) Should the fine aggregate contain less than 5 per cent of any of the sizes specified in Paragraph (*a*), that size shall not be tested but, for the purpose of calculating the test results, shall be considered to have the same loss in sodium-sulfate or magnesium-sulfate treatment as the average of the sizes tested.

Preparation of Test Sample

5. The sample shall be thoroughly washed on a No. 100 sieve and dried to constant weight at a temperature of 105 to 110 C. (221 to 230 F.) and separated into the different sizes by sieving as follows:

Make a rough separation of the graded sample by means of a nest of the standard sieves specified in Section 4. From the fractions obtained in this manner select samples of sufficient size to yield 100 g. after sieving to refusal. (In general, a 110-g. sample will be sufficient.) Fine aggregate sticking in the meshes of the sieves shall not be used in preparing the samples. Samples consisting of 100 g. shall be weighed out of each of the separated fractions after final sieving and placed in separate containers for the test.

Storage of Samples in Solution

6. The samples shall be immersed in the prepared solution of sodium sulfate or magnesium sulfate for 18 hr. in such a manner that the solution covers them to a depth of at least ½ in. The containers shall be covered to reduce evaporation and prevent the accidental addition of extraneous substances. The samples immersed in the sodium-sulfate solution shall be maintained at a temperature (Note) of 21 C. ±1 C. (70 F. ±2 F.) for the 18-hr. period.

NOTE.—A moist room such as is used for curing concrete and mortar test specimens offers a convenient means of controlling the storage temperature. The presence of a few crystals of sodium sulfate or magnesium sulfate in the container is essential to keeping the solution saturated.

Attention is called to the fact that it is not necessary to control the temperature of the magnesium-sulfate solution, as the solubility of this salt is practically constant at laboratory temperatures between 20 to 30 C. (68 to 86 F.). However, it is necessary to keep a saturated solution which can be done by maintaining the specific gravity of the solution at not less than 1.29 at 25 C. (77 F.) as determined with a hydrometer.

Drying Samples After Immersion

7. After the 18-hr. immersion period the aggregate samples shall be removed from the solution and placed in the drying oven. The temperature of the oven shall have been brought previously to 105 to 110 C. (221 to 230 F.). Care shall be exercised to avoid loss of any of the aggregate particles or detritus coarser than a No. 100 sieve. The samples shall be dried to constant weight at the specified temperature. After drying the samples shall be allowed to cool to room temperature, when they shall again be immersed in the prepared solution as described in Section 6.

Cycles

8. The process of alternate immersion and drying shall be repeated until the required number of cycles is obtained.

Examination

9. The examination (Note) of the test sample shall be made as follows:

(*a*) After the completion of the final cycle and after the sample has cooled, the sample shall be washed free from the sodium sulfate or magnesium sulfate as determined by the reaction of the wash water with barium chloride ($BaCl_2$).

(*b*) After the sodium sulfate or magnesium sulfate has been removed, each fraction of the sample shall be dried to constant weight at 105 to 110 C. (221 to 230 F.), weighed and screened over the same sieve on which it was retained before the test. The particles retained on this sieve shall be weighed and the weight recorded.

NOTE.—In addition to the procedure described in Paragraphs (*a*) and (*b*), the following is suggested as giving additional information of value:

Each fraction should be examined visually in order to determine if there is any evidence of excessive splitting of the grains.

Report

10. The report shall include the following data (Note):

(*a*) Weight of each fraction of sample before test.

(*b*) Material from each fraction of sample, finer than sieve on which fraction was retained before test, expressed as a percentage by weight of the fraction.

(*c*) Weighted average calculated from the percentages of loss for each fraction and based on the grading of the sample as received for examination.

(*d*) Character of solution (sodium or magnesium sulfate).

NOTE.—The following table, shown with test values inserted for purpose of illustration, is a suggested form for recording test data:

Chemical Used in Test..............................Magnesium Sulfate

Sieve Size		Grading of Original Sample, per cent	(a) Weight of Test Fractions Before Test, g.	(b) Percentage Passing Finer Sieve After Test (Actual per cent Loss)	(c) Weighted Average (Corrected per cent Loss)
Passing	Retained on				
No. 100........	....	5.0	....	....	....
No. 50........	No. 100........	11.4	100	3.5	0.40
No. 30........	No. 50........	26.0	100	4.2	1.09
No. 16........	No. 30........	25.2	100	4.8	1.21
No. 8........	No. 16........	17.0	100	8.0	1.36
No. 4........	No. 8........	10.8	100	11.2	1.21
⅜-in........	No. 4........	4.6	....	6.3[a]	0.29
Totals........		100.0	500	....	5.56

[a] The average percentage loss (6.3 per cent) of all sizes tested is used as the percentage loss for this size, since this size contains less than 5 per cent of the original sample as received. See Section 5.

After treating each separate fraction of sample as described in Paragraph (*b*), all sizes, including the detritus, shall be combined and a sieve analysis made using as many of the following sieves as are required: Nos. 100, 50, 30, 16, 8, 4. The results of the sieve analysis shall be recorded as cumulative percentages retained on each sieve.

TENTATIVE METHOD OF TEST
FOR
DETERMINATION OF VOIDS IN COARSE AGGREGATE FOR CONCRETE (DRY RODDED)[1]

A.S.T.M. Designation: C 30 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Percentage of Voids

1. The voids in dry rodded coarse aggregate shall be determined by the following formula:

$$\text{Percentage of voids} = \frac{(\text{sp. gr.} \times 62.355) - \text{Wt.}}{\text{sp. gr.} \times 62.355} \times 100$$

where sp. gr. = the apparent specific gravity of the coarse aggregate as determined by the method referred to in Section 2 (*a*)

62.355 = the weight in pounds of 1 cu. ft. of water at the standard temperature of 16.7 C. (62 F.)

Wt. = the weight in pounds per cubic foot of the coarse aggregate as determined by the method referred to in Section 2 (*b*)

Methods of Testing

2. The specific gravity and weight of the aggregate shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Specific Gravity.*—Standard Method of Test for Apparent Specific Gravity of Coarse Aggregates (A.S.T.M. Designation: D 30).[2]

(*b*) *Weight of Coarse Aggregate.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[3]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M Committee C-9 on Concrete and Concrete Aggregates.

This tentative method, when adopted as standard, will be added to the present Standard Method of Tes for Determination of Voids in Fine Aggregate for Concrete (A.S.T.M. Designation: C 30 – 22), see 1933 Boo of A.S.T.M. Standards, Part II, p. 249.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 994.

[3] *Ibid.*, p. 247.

TENTATIVE SPECIFICATIONS
FOR
CLASSIFICATION OF COALS BY RANK[1]

A.S.T.M. Designation: D 388 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1934; Revised, 1935.

Scope

1. These specifications cover the classification of coals by rank, that is, according to their degree of metamorphism, or progressive alteration, in the natural series from lignite to anthracite.

Basis of Classification

2. The basic scheme of classification is according to fixed carbon and calorific value (expressed in B.t.u.) calculated to the mineral-matter-free basis. The higher-rank coals are classified according to fixed carbon on the dry basis; and the lower-rank coals according to B.t.u. on the moist basis. Agglutinating and slacking indices are used to differentiate between certain adjacent groups.

Classification by Rank

Classification by Rank

3. (*a*) *Fixed Carbon and B.t.u.*—Coals shall be classified by rank in accordance with Table I. Coals having calorific values of 14,000 B.t.u. or more on the moist, mineral-matter-free basis, and coals having fixed carbon of 69 per cent or more on the dry, mineral-matter-free basis, shall be classified according to fixed carbon on the dry, mineral-matter-free basis; coals having calorific values less than 14,000 B.t.u. on the moist, mineral-matter-free basis shall be classified according to B.t.u. on the moist, mineral-matter-free basis, provided the fixed carbon on the dry, mineral-matter-free basis is less than 69 per cent.

(*b*) *Weathering Index.*—Coals showing average weathering indices of less than 5 per cent shall be considered non-weathering, coals showing average weathering indices of 5 per cent or more shall be considered weathering from the standpoint of classification.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the Sectional Committee on Classification of Coals functioning under the procedure of the American Standards Association with the American Society for Testing Materials as sponsor.

(*c*) *Agglutinating Index.*—Coals having average agglutinating indices of 500 g. or more at a ratio of 15 parts sand to 1 part coal shall be considered agglutinating from the standpoint of classification.

TABLE I.—CLASSIFICATION OF COALS BY RANK.

Legend: F.C. = Fixed Carbon. V.M. = Volatile Matter. B.t.u. = British thermal units.

Class	Group	Limits of Fixed Carbon or B.t.u. Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite	Dry F.C., 98 per cent or more (Dry V.M., 2 per cent or less)	
	2. Anthracite	Dry F.C., 92 per cent or more and less than 98 per cent (Dry V.M., 8 per cent or less and more than 2 per cent)	
	3. Semianthracite	Dry F.C., 86 per cent or more and less than 92 per cent (Dry V.M., 14 per cent or less and more than 8 per cent)	Non-agglutinating[a]
II. Bituminous[c]	1. Low volatile bituminous coal	Dry F.C., 78 per cent or more and less than 86 per cent (Dry V.M., 22 per cent or less and more than 14 per cent)	
	2. Medium volatile bituminous coal	Dry F.C., 69 per cent or more and less than 78 per cent (Dry V.M., 31 per cent or less and more than 22 per cent)	
	3. High volatile *A* bituminous coal	Dry F.C., less than 69 per cent (Dry V.M., more than 31 per cent); and moist[b] B.t.u., 14,000[d] or more	
	4. High volatile *B* bituminous coal	Moist[b] B.t.u., 13,000 or more and less than 14,000[d]	
	5. High volatile *C* bituminous coal	Moist B.t.u., 11,000 or more and less than 13,000[d]	Either agglutinating or non-weathering[e]
III. Subbituminous	1. Subbituminous *A* coal	Moist B.t.u., 11,000 or more and less than 13,000[d]	Both weathering and non-agglutinating
	2. Subbituminous *B* coal	Moist B.t.u., 9500 or more and less than 11,000[d]	
	3. Subbituminous *C* coal	Moist B.t.u., 8300 or more and less than 9500[d]	
IV. Lignitic	1. Lignite	Moist B.t.u., less than 8300	Consolidated
	2. Brown coal	Moist B.t.u., less than 8300	Unconsolidated

[a] If agglutinating, classify in low-volatile group of the bituminous class.

[b] Moist B.t.u. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[c] Pending the report of the Subcommittee on Origin and Composition and Methods of Analysis, it is recognized that there may be non-caking varieties in each group of the bituminous class.

[d] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of B.t.u.

[e] There are three varieties of coal in the High-volatile *C* bituminous coal group, namely, Variety 1, agglutinating and non-weathering; Variety 2, agglutinating and weathering; Variety 3, non-agglutinating and non-weathering.

Symbols for Expressing Classification

4. (*a*) The position of a coal in the scale of rank may be expressed in condensed form as in the following example:

$$(62 — 146)$$

in which the parenthesis signifies that the contained numbers are on the mineral-matter-free basis. The first number represents fixed carbon on the dry basis, reported to the nearest whole per cent. The second number represents B.t.u. on the moist basis, expressed as hundreds of B.t.u. (to the nearest hundred); for example, 14,580 B.t.u. would be represented as 146.

(*b*) When agglutinating or weathering properties enter into the classification of a coal, they shall be expressed outside and immediately following the parenthesis by the following symbols:

ag. = agglutinating
na. = non-agglutinating
we. = weathering
nw. = non-weathering.

(*c*) Symbols describing the grade of coal shall be placed after the parenthesis, as shown in the following illustration:

(62–146) 132–A8–F24–S1.6

The numbers in parenthesis are on the mineral-matter-free basis, and give the position of the coal in the scale of rank as explained in Paragraph (*a*) of this section. The numbers and symbols following the parenthesis show the position of the coal according to classification by grade as shown in Section 2 of the Tentative Specifications for Classification of Coals by Grade (A.S.T.M. Designation: D 389 – 34 T) of the American Society for Testing Materials.[1] That is, 132–A8–F24–S1.6 indicates a heating value of approximately 13,200 B.t.u., an ash content of 6.1 to 8.0 per cent, inclusive, an ash-softening temperature of 2400 to 2590 F., inclusive, and a sulfur content of 1.4 to 1.6 per cent, inclusive, all expressed on the basis of the coal as sampled.

SAMPLING

Bed Samples

5. (*a*) The classification of a coal bed, or part of a coal bed, in any locality shall be based on the average analysis and calorific value (and agglutinating and weathering index where required) of not less than three and preferably five or more face samples taken in different and uniformly distributed localities, either within the same mine or closely adjacent mines representing a continuous and compact area not greater than approximately four square miles in regions of geological uniformity. In regions where conditions indicate that the coal probably varies rapidly in short distances the spacing of samples and grouping of analyses to provide average values shall not be such that coals of obviously different rank will be used in calculating average values.

(*b*) The samples shall be taken in accordance with the U. S. Bureau of Mines method[2] or its equivalent, and shall be placed in moisture-tight containers in the mine.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 841 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 624.

[2] J. A. Holmes, "The Sampling of Coal in the Mine," U. S. Bureau of Mines *Technical Paper No. 1* (1918).

(*c*) Analyses of samples from outcrops or from weathered or oxidized coal shall not be used for classification by rank.

(*d*) In case the coal is likely to be classified on the "moist" basis, that is, containing the natural bed-moisture, the samples shall be taken at freshly exposed faces, which are free from visible surface moisture if possible. Samples of low-rank coals which appear dry at the time of collection frequently give off moisture which condenses on the inner surface of the sample containers, before they are opened for analysis. In the case of coals which were free from visible surface moisture when sampled, but which show moisture on the inner surface of the containers when opened, both the container and the coal shall be weighed before and after air-drying and the total loss in weight shall be reported as air-drying loss.

(*e*) If it is impossible to sample the coal without including visible surface moisture, and the coal is likely to be classified on the "moist" basis, the sampler shall include the following statement in the description: "Sample contains surface moisture." Samples so marked shall not be used for classification on a moist basis unless brought to a standard condition of moisture equilibrium at 30 C. in a vacuum desiccator containing a saturated solution of potassium sulfate (97 per cent humidity) as suggested by Stansfield and Gilbart.[1] Analyses of such wet samples which have been treated in this manner shall be designated as "wet samples equilibrated at 30 C. and 97 per cent humidity."

Tipple or Shipment Samples

6. (*a*) The classification of "run of mine" coal and prepared sizes of coal shall be based on representative samples taken in accordance with the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials.[2]

(*b*) In case the coal is likely to be classified on the "moist" basis, the samples shall be taken at the tipple or preparation plant and protected against loss of moisture as specified in Sections 8 and 9 of the Standard Method D 21. Samples which appear dry at the time of collection shall be handled in accordance with Section 5 (*d*) above to ensure correct determination of total air-drying loss. Samples which have visible surface moisture on the coal when sampled, and which are likely to be classified on the "moist" basis, shall be marked by the sampler, equilibrated, and the analyses designated in accordance with Section 5 (*e*) above.

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[1] Edgar Stansfield and K. C. Gilbart, "Moisture Determination for Coal Classification," *Transactions*, Am. Inst. Mining and Metallurgical Engrs., Coal Division, p. 125 (1932).

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 318.

METHODS OF ANALYSIS AND TESTS

Laboratory Sampling and Analysis

7. The coal shall be prepared and analyzed in accordance with the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials.[1]

Weathering or Slacking Index

8. Pending the adoption of a method by the American Society for Testing Materials, the weathering or slacking characteristics of coals shall be determined by the U. S. Bureau of Mines method[2] modified with respect to the selection of a standard humidity. Briefly, the test consists of air-drying 500 to 1000 g. of approximately 1 to $1\frac{1}{2}$ in. lumps at a temperature of 30 to 35 C. and a humidity of 30 to 35 per cent for a period of 24 hr. and then immersing the lumps in water for 1 hr.; the water then being drained off, and the sample again air-dried for 24 hr. The amount of disintegration is determined by sieving on an 8-in. wire-mesh sieve with 0.263-in. square openings, and weighing the quantity of coal passing (undersize) and that retained on (oversize) the sieve. The percentage of coal passing the sieve (undersize), after deducting a blank sieving test, is the weathering or slacking index of the coal.

Agglutinating Index

9. Pending consideration of an agglomeration test now being investigated, the agglutinating index shall be determined in accordance with the Proposed Method of Test for Agglutinating Value of Coal, published as information by the American Society for Testing Materials.[3]

CALCULATION TO MINERAL-MATTER-FREE BASIS

Calculation of Fixed Carbon and B.t.u.

10. (*a*) For classification of coal according to rank, fixed carbon and B.t.u. shall be calculated to the mineral-matter-free basis in accordance with either the Parr formulas[4] (1), (2) and (3) or the approximation formulas (4), (5) and (6) given below. In case of litigation the appropriate Parr formula shall be used.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 269.

[2] A. C. Fieldner, W. A. Selvig and W. H. Frederic, "Accelerated Laboratory Test for Determination of Slacking Characteristics of Coal," U. S. Bureau of Mines *Report of Investigations No. 3055* (1930).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 457 (1934).

[4] S. W. Parr, "The Classification of Coal," *Bulletin No. 180*, Engineering Experiment Station, University of Illinois (1928).

Calculation from "moist" basis:

Parr Formulas:

$$\text{Dry, Mm-free F.C.} = \frac{\text{F.C.} - 0.15\text{S}}{100 - (\text{M} + 1.08\text{A} + 0.55\text{S})} \times 100 \ldots\ldots (1)$$

$$\text{Dry, Mm-free V.M.} = 100 - \text{Dry, Mm-free F.C.} \ldots\ldots (2)$$

$$\text{Moist, Mm-free B.t.u.} = \frac{\text{B.t.u.} - 50\text{S}}{100 - (1.08\text{A} + 0.55\text{S})} \times 100 \ldots\ldots (3)$$

Note.—The above formula for fixed carbon is derived from the Parr formula for volatile matter.

Approximation Formulas:

$$\text{Dry, Mm-free F.C.} = \frac{\text{F.C.}}{100 - (\text{M} + 1.1\text{A} + 0.1\text{S})} \times 100 \ldots\ldots (4)$$

$$\text{Dry, Mm-free V.M.} = 100 - \text{Dry, Mm-free F.C.} \ldots\ldots (5)$$

$$\text{Moist, Mm-free B.t.u.} = \frac{\text{B.t.u.}}{100 - (1.1\text{A} + 0.1\text{S})} \times 100 \ldots\ldots (6)$$

where:

Mm = mineral matter;
B.t.u. = British thermal units;
F.C. = percentage of fixed carbon;
V.M. = percentage of volatile matter;
M = percentage of moisture;
A = percentage of ash;
S = percentage of sulfur;

Moist refers to coal containing its natural bed moisture, but not including visible water on the surface of the coal. See Section 5 (*d*) and (*e*) and Section 6 (*b*) above.

Modification for Coals High in Carbonate

(*b*) In case of controversy, samples containing more than 1.0 per cent of carbon dioxide occurring as carbonates shall be either (1) crushed to pass through an 840-micron (No. 20) sieve and floated on a heavy liquid of such specific gravity as to reduce the carbon dioxide occurring as carbonate to 1.0 per cent or less on a dry basis, provided, however, that the recovery of float coal shall not be less than 75 per cent; or (2) shall be analyzed for mineral matter according to the Parr method[1] for coals with high calcium carbonate content. In case of litigation, method (1) shall be used.

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[1] S. W. Parr, "Chemical Study of Illinois Coal," Illinois Coal Mining Investigations, State Geological Survey, Urbana, Ill., *Bulletin No. 3*, p. 35 (1916).

APPENDIX

PUBLISHED ANALYSES SUITABLE FOR COAL CLASSIFICATION

Only such published analyses as have been made in accordance with the standard methods of the American Society for Testing Materials shall be used in the classification of coal; and if classification is on the basis of moist B.t.u., then only those samples which have been taken and transported to the laboratory in such a manner as to preserve the true moisture content of the coal shall be used. In general, the principal sources of published analyses of samples suitable for coal classification are the publications of the U. S. Bureau of Mines, the U. S. Geological Survey, and the Canadian Department of Mines. Suitable analyses are published also by some of the State Surveys and some of the Provinces of Canada. However, it must be kept in mind that many of the bed sample analyses of the governmental organizations are from prospects in which the coal may have been altered by exposure. Such samples shall not be used for classification. Analyses published prior to 1904 are unlikely to represent the true moisture content of coal, and even after this date, analyses from sources other than governmental laboratories are not likely to be representative with respect to moisture.

In view of the importance of the fixed carbon determination in coal classification, special attention is called to the 1913 revision in this method by the American Chemical Society.[1] The new revision was substantially the same as that introduced by the U. S. Bureau of Mines[2] a few years earlier, as a result of finding large discrepancies between results of the Pittsburgh, Pa., and Washington, D. C., laboratories. A considerable number of analyses were made before it was discovered that the natural-gas burners at the Pittsburgh laboratory gave high results for fixed carbon.[3] For this reason, the fixed carbon results of the U. S. Geological Survey or U. S. Bureau of Mines analyses designated by Laboratory Nos. 5147 to 9120, inclusive, shall not be used for the classification of coal.

All analyses made by any laboratory prior to 1913 should be rejected unless there is positive evidence that the methods of analysis were essentially those adopted by the American Society for Testing Materials in 1913.

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[1] Preliminary Report of the Committee on Coal Analysis of the American Society for Testing Materials and the American Chemical Society, *Journal of Industrial and Engineering Chemistry*, Vol. 5, p. 517 (1913); see also Report of Subcommittee IV on Volatile Matter, *Proceedings*, Am. Soc. Testing Mats., Vol. XIV, Part I, p. 424 (1914).

[2] A. C. Fieldner, "Notes on the Sampling and Analysis of Coal," U. S. Bureau of Mines *Technical Paper No. 76*, p. 16 (1914).

[3] N. W. Lord, J. A. Holmes, F. M. Stanton, A. C. Fieldner and S. Sanford, "Analyses of Coals in the United States," U. S. Bureau of Mines *Bulletin No. 22*, Part I, p. 28 (1913).

TENTATIVE METHOD OF TEST

FOR

GRINDABILITY OF COAL BY THE BALL-MILL METHOD[1]

A.S.T.M. Designation: D 408 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method describes a laboratory procedure for estimating the grindability of coal.[2] Briefly, the relative amounts of energy necessary to pulverize different coals is determined by placing a sample of coal in a ball mill and finding the number of revolutions required to grind it so that 80 per cent of the sample passes a 74-micron (No. 200) A.S.T.M. sieve.

Apparatus

2. The apparatus for the grindability test shall consist of the following:

(*a*) *Ball Mill.*—A cylindrical steel mill 8 in. in length and $8\frac{1}{8}$ in. in diameter, inside dimensions, and $\frac{1}{4}$ in. in thickness shall be used. Three steel lifters, each $\frac{7}{16}$ in. square and 8 in. in length, shall be riveted longitudinally at 120-deg. intervals to the inside wall of the mill. They shall be so fastened that no space is left between the wall and the lifters. The lid shall be fitted to the mill by means of a rubber gasket and held securely in place by the yoke and crossbar arrangement ordinarily employed with laboratory porcelain jar mills. A suitable mill can be made of a section of ordinary 8-in. water pipe with a bottom and lid of $\frac{1}{4}$-in. steel plate. The bottom may be welded to the pipe section.

(*b*) *Ball Charge.*—The charge for the mill shall consist of 100 steel ball bearings, each 1 in. in diameter.

NOTE.—Ball bearings are specified because they are of uniform diameters and smoothly polished.

(*c*) *Rotation of Mill.*—The mill shall be rotated in a horizontal position about its cylindrical axis at 40 r.p.m. The jar-mill frame used for pulverizing coal samples for analysis is suitable for this purpose. A revolution-counter shall be used to show the number of revolutions of the mill.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-5 on Coal and Coke.

[2] For information concerning the experimental work on which this method is based, see the paper by H. F. Yancey, O. L. Furse and R. A. Blackburn, "Estimation of the Grindability of Coal," *Transactions*, Am. Inst. Mining and Metallurgical Engrs., Vol. 108, p. 267 (1934).

(*d*) *Sieves.*—The following sieves will be required: 1680-micron (No. 12), 10 in. or more in diameter; and a 74-micron (No. 200), 10 in. in diameter. The sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1]

Gross Sample

3. A representative gross sample of coal shall be collected and prepared in accordance with the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials.[2] Approximately 10 lb. of coal crushed to pass a 4760-micron (No. 4) sieve shall constitute the laboratory sample.

Preparation of Sample

4. The 10-lb. laboratory sample shall be treated by a graded roll crushing procedure[3] in order to minimize the production of fine sizes of coal. First, the 10-lb. lot shall be passed in a thin stream through a laboratory-type double-roll crusher set with a spacing of $\frac{1}{4}$ in. between the rolls. The sample shall then be divided into two equal parts by riffling and one part discarded. The remaining 5-lb. portion shall then be screened on the 1680-micron (No. 12) sieve and the oversize passed through the rolls with a spacing between the rolls set at $\frac{3}{16}$ in. The product of the crushing operation shall be again screened on the 1680-micron (No. 12) sieve and the undersize combined with that previously obtained. The oversize now remaining on the 1680-micron (No. 12) sieve shall be further reduced in size by successions of crushing with the clearance between the rolls set at $\frac{1}{8}$, $\frac{1}{16}$, and $\frac{1}{32}$ in., respectively. Material finer than the 1680-micron (No. 12) sieve shall be removed after each crushing and only the oversize shall be crushed at the next closer roll setting. The 5-lb. lot shall then be thoroughly mixed and divided into two equal parts by riffling; one part being set aside as a reserve sample. The other part shall be air-dried at room temperature to constant weight and then screened on the 74-micron (No. 200) sieve to remove the undersize, which shall be discarded.

Test Procedure

5. A 500-g. sample of the air-dried product sized between the 1680-micron (No. 12) and 74-micron (No. 200) sieves shall be obtained by riffling. The charge of 100 balls shall be placed in the mill and the 500-g. sample added. Then the mill shall be closed and rotated at 40 r.p.m. for 50 revolu-

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

[2] *Ibid.*, p. 318.

[3] C. E. Baltzer and H. P. Hudson, "A Method for Rating the Grindability or Pulverizability of Coal, Developed by the Fuel Research Laboratories (F.R.L.), Department of Mines, Canada," *Report No. 737-1*, Department of Mines, Mines Branch, Canada (1933).

tions. The contents of the mill shall then be poured onto a sieve coarse enough to retain the balls but not the coal. The mill and balls shall be brushed to remove the coal and the product shall be screened on the 74-micron (No. 200) sieve until not more than 0.5 g. passes in 1 min. of screening. The undersize shall then be weighed and the number of revolutions required to increase its weight to 50 g. shall be calculated by direct proportion. This number of revolutions constitutes a "cycle." Both the oversize and the undersize shall be returned to the mill and it shall be rotated for the additional number of revolutions required to complete the cycle. Again the mill shall be removed from the frame and the contents screened on the 74-micron (No. 200) sieve as before. The undersize product including the loss, which usually ranges from 1 to 3 g. and is assumed to belong to the undersize, should weigh between 45 and 55 g. These operations comprise the first cycle. For the second cycle the oversize only shall be returned to the mill and ground for the number of revolutions previously found necessary to give approximately 10 per cent of undersize. The material finer than the 74-micron (No. 200) sieve shall be removed as before. The same procedure of alternate milling of the oversize and removal of the undersize shall be continued with the same number of revolutions per cycle until at least 80 per cent or 400 g. of the original sample passes the 74-micron (No. 200) sieve. The endpoint of the test shall be considered as the number of revolutions required to grind exactly 80 per cent of the sample. This exact number of revolutions shall be determined by interpolation.

Number of Tests

6. Duplicate tests shall be made. In the second test the preliminary step taken in the first test to determine the number of revolutions necessary to give 45 to 55 g. of undersize shall be omitted. The number of revolutions per cycle shall be the same in both tests.

Precision of Tests

7. Duplicate tests made in the same laboratory shall agree within 50 revolutions.

Expression of Results

8. The average number of revolutions necessary to grind the sample so that 80 per cent of it passes the 74-micron (No. 200) sieve shall be expressed in the following two ways:

$$\text{Grindability, lb. per hr.} = \frac{2645}{\text{Average number of revolutions}}$$

$$\text{Grindability, per cent} = \frac{72{,}000}{\text{Average number of revolutions}}$$

TENTATIVE METHOD OF TEST

FOR

GRINDABILITY OF COAL BY THE HARDGROVE-MACHINE METHOD[1]

A.S.T.M. Designation: D 409 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method[2] is used to determine the relative grindability or ease of pulverizing of coals in comparison with a coal chosen as 100 grindability. The method is based on Rittinger's Law, which states: "The work done in pulverizing is proportional to the new surface produced." A prepared sample receives a definite amount of grinding energy in a miniature pulverizer and the new surface is determined by sieving.

Apparatus

2. The apparatus for the grindability test shall consist of the following:

(a) *Grindability Machine.*—A grindability machine such as is shown in Fig. 1 is required for this test. The eight 1-in. balls roll on a stationary ring and are driven from above by a rotating ring. The action of the rolling balls causes an increase in the surface of the sample being tested. A definite pressure of 64 lb. on the balls is obtained by the weights, shaft, top grinding ring and gear. A predetermining counter is used to stop the motor automatically as soon as the vertical shaft of the grindability machine has made exactly 60 revolutions.

(b) *Sieves.*—The following sieves will be required: 1190-micron (No. 16), 590-micron (No. 30), 250-micron (No. 60), 149-micron (No. 100), 105-micron (No. 140), 74-micron (No. 200), 62-micron (No. 230), and 44-micron (No. 325). The sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3]

(c) *Mechanical Sieving Device.*—A mechanical sieving device is desirable, although not necessary. If a mechanical sieving device is not avail-

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-5 on Coal and Coke.

[2] For information concerning the experimental work on which this method is based, see paper by R. M. Hardgrove, "Grindability of Coal," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 54, F.S.P., p. 37 (1932).

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

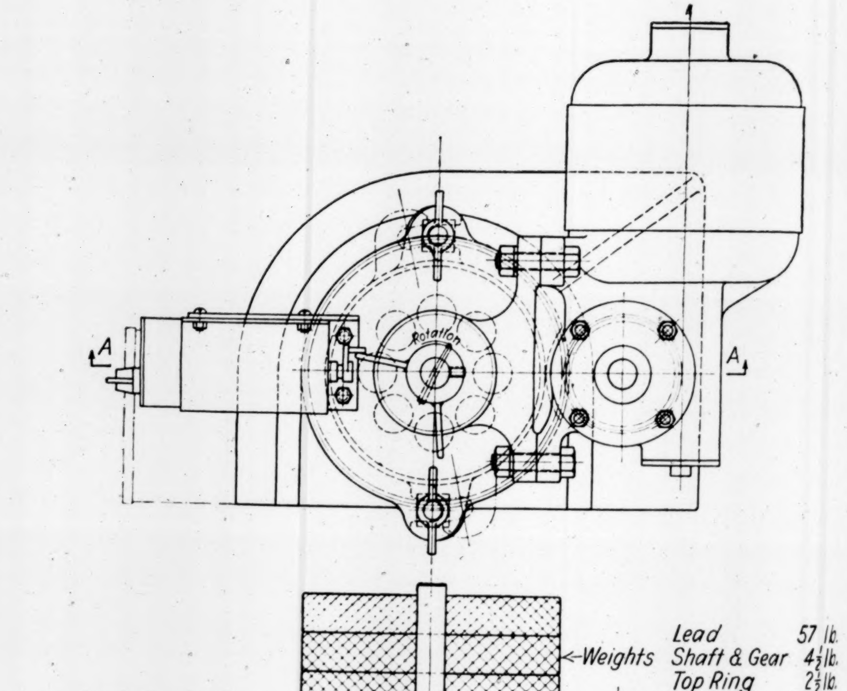
A
A
Rotation
Lead 57 lb.
Shaft & Gear 4½ lb.
Top Ring 2½ lb.
Total 64 lb.
Weights
Predetermined Revolution Counter
Contactor
Grease Seal
Integral Motor and Reducing Gears
Lower Grinding Element
Top Grinding Element
Section "A-A"

FIG. 1.—Hardgrove Grindability Machine.

able, it will be necessary to give the sample an equivalent amount of hand sieving.

(*d*) *Balance.*—A triple beam balance having a sensitivity of 1 cg., and with which weighings from 1 cg. to 111 g. can be made, is well adapted for this test. However, a torsion or trip balance with suitable pan, and of the specified sensitivity may be used. Greater sensitivity than 1 cg. is not necessary for this test.

(*e*) *Laboratory Crusher.*—The sizing of the sample to be placed in the grindability machine shall be such that it will pass the 1190-micron (No. 16) sieve, and remain on the 590-micron (No. 30) sieve. In order to break up the coarser particles of the sample being prepared for test, a laboratory crusher or a coffee mill will be found desirable. The use of such a device allows the reduction of the coarser particles without the production of excess fine material.

Gross Sample

3. A representative gross sample of coal shall be collected and prepared in accordance with the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials.[1]

Preparation of Sample

4. An air drier and a riffle sampler, as described in Section 1 (*a*) and (*h*), respectively, of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials,[2] or equivalent are desirable in preparing the sample. The laboratory sample, after air drying until the loss in weight is not more than 0.1 per cent per hour, shall be placed on the 1190-micron (No. 16) sieve nested with a 590-micron (No. 30) sieve and bottom pan. The sieves shall be shaken by a mechanical sieving machine for approximately 2 min., or given an equivalent amount of hand sieving. The material remaining on the 1190-micron (No. 16) sieve shall be put into a laboratory crusher or a coffee mill in which the set screw has been adjusted so that the coarsest particles are broken up. The sample after passing through the laboratory crusher or coffee mill shall be returned to the 1190-micron (No. 16) sieve of the nest of sieves and again shaken by the mechanical sieving machine or hand sieved. This operation shall be repeated several times until the entire sample has passed through the 1190-micron (No. 16) sieve. The material remaining on the 590-micron (No. 30) sieve shall then be shaken to thoroughly remove any material smaller than this size. All material passing the 590-micron (No. 30) sieve shall be discarded. By using this method of preparing the sample, a minimum of fines is produced.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 318.
[2] *Ibid.*, p. 269.

Operation of Grindability Machine

5. The predetermined counter shall be set so that the machine will automatically stop after 60 revolutions have been completed. To insure stoppage of the machine within one quarter of one revolution, two trippers are furnished. One tripper is fixed, and the other may be set to correspond with the coasting of the machine after the switch is opened. Therefore, the number of counts on the counter will be 120, or just twice the number of revolutions made by the machine. The grinding elements shall be thoroughly cleaned by brushing before the sample to be tested is added. The eight 1-in. diameter balls shall be placed in the bottom of the lower grinding element and 50 g. of the prepared No. 16 to No. 30 size sample shall be distributed evenly over the balls. Any material falling on the elevated section of the lower grinding element shall be brushed toward the balls. The upper grinding element shall then be placed on the balls and the lower end of the shaft shall be fitted to the square opening in the disk and the grinding elements securely fastened in place by two thumb screws on the sides of the lower grinding element. Care shall be taken to pull the bowl up evenly with the thumb screws. The set screw on the collar which supports the driving gears shall always be kept tight, otherwise the weights will rest on the frame and there will be no pressure on the balls. The predetermining counter shall be set to zero, and the starting switch closed. After the machine has been automatically stopped, the sample shall be transferred to the 590-micron (No. 30) sieve of the nest of sieves. The sieves used and the order in which they are nested shall be as follows:

	SIEVE
Top	590-micron (No. 30)
Second	250-micron (No. 60)
Third	149-micron (No. 100)
Fourth	105-micron (No. 140)
Fifth	74-micron (No. 200)
Sixth	62-micron (No. 230)
Bottom	44-micron (No. 325)

Sieving

6. The nest of sieves shall be shaken by a mechanical sieving machine for 10 min., or given an equivalent amount of hand sieving. The sieves shall then be separated and the underside of each carefully brushed (Note) while holding the sieve in an inclined position in such a way that any particles removed by brushing fall on the sieve beneath, thus keeping the loss of any portion of the sample at a minimum. The sample shall then be shaken by the mechanical sieving machine for 5 min. more or given an equivalent amount of hand sieving, after which the brushing of the underside of each sieve shall be repeated. After an additional 5 min. of sieving, the material is ready for weighing. A total of 20 min. of mechanical

sieving, or an equivalent amount of hand sieving, should result in comparatively clean sieves.

NOTE.—A 1-in. bristle brush is satisfactory for brushing the underside of the wire cloth.

Weighing the Sample

7. Coals having a high residual moisture content (this is especially true of lignites) lose some of their residual moisture when in a pulverized condition. For this reason rapid and fairly accurate weighing is essential. Accumulative weighing is used to weigh the screened portion to eliminate the necessity of cleaning the pan after weighing the contents of each sieve. The material remaining on the 590-micron (No. 30) sieve shall be transferred to the balance pan and weighed to within 0.1 g. and the weight recorded. The contents of the 250-micron (No. 60) sieve shall be added to the material on the balance pan and weighed, and the weight recorded. The contents of each succeeding sieve shall be thus weighed accumulatively. The weight of material between any two screens may be determined by subtraction. The amount of material passing the 44-micron (No. 325) sieve shall be taken as the difference between the original weight of the sample taken and the accumulated weight of the material retained on sieves Nos. 16, 30, 60, 100, 140, 200, 230, and 325.

Calculation of Results

8. After weighing the sieved portions of the pulverized sample, it is necessary to determine the surface units produced in order to obtain the grindability of the material. A typical calculation is as follows:

DESIGNATION				
MICRON DESIGNATION	U. S. STANDARD SIEVE SERIES NUMBER	GRAMS OF MATERIAL BETWEEN THE TWO SIEVES	SURFACE UNIT FACTOR[a]	FINAL SURFACE UNITS
1190 to 590	Nos. 16 to 30	14.3	1.35	19.3
590 to 250	Nos. 30 to 60	17.3	2.86	49.5
250 to 149	Nos. 60 to 100	6.4	6.02	38.6
149 to 105	Nos. 100 to 140	3.2	9.45	30.3
105 to 74	Nos. 140 to 200	2.2	13.4	29.5
74 to 62	Nos. 200 to 230	1.4	17.7	24.8
62 to 44	Nos. 230 to 325	0.6	22.6	13.6
44	Passing 325	4.6	47.5	219.0
		50.0		424.6

---

[a] The surface unit factor is obtained as follows:

$$\text{Surface Unit Factor} = \frac{1200}{\frac{Y_1 + Y_2}{2}}$$

where Y_1 and Y_2 = the openings of the two screens expressed in microns.

As 50 g. are used, the "surface units" are equivalent to specific surface in square centimeters per gram with a specific gravity of 1. A better way of defining surface units is "square centimeter per cubic centimeter of solid material."

Final surface units of sample	424.6
Original surface units	67.5
New surface units produced	357.1

New surface units of 100 grindability sample[a] = 656

$$\text{Grindability} = \frac{\text{New surface units produced}}{\text{New surface units of 100 grindability coal}} = \frac{357.1}{656} = 54.4$$

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[a] The 100 grindability coal is a low volatile run-of-mine coal from the Jerome Mine, Upper Kittanning bed, Somerset County, Pa. Due to the variations in sieves within the specified tolerance, it is desirable to determine the new surface produced by the 100 grindability coal each time a new set of sieves is placed in service.

Permissible Variations

9. The permissible variation between two or more determinations shall not exceed the values as specified below:

	PER CENT
Same laboratory	2
Different laboratories	3

TENTATIVE METHOD OF TEST
FOR
SCREEN ANALYSIS OF COAL[1]

A.S.T.M. Designation: D 410 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method shall apply to all coal except anthracite, powdered coal as used in boiler plants, and crushed coal as charged into coke ovens.

APPARATUS

Screens

2. Screens of the following series shall be used:

(*a*) *Gage Rings or Plates.*—Gage rings or gage plates with 8, 6, and 5-in. diameter openings. The actual diameters of openings shall not vary from the nominal diameters more than ± 3 per cent.

(*b*) *Round-Hole Screens.*—Round-hole screens with 4, 3, 2½, 2, 1½, 1¼, 1, ¾, ½, and ⅜-in. diameter openings, conforming to the Standard Specifications for Round-Hole Screens for Testing Purposes (A.S.T.M. Designation: E 17) of the American Society for Testing Materials.[2]

(*c*) *Sieves.*—Wire-cloth sieves with square openings, 4760-micron (No. 4), 2380-micron (No. 8), 1190-micron (No. 16), 590-micron (No. 30), 297-micron (No. 50), 149-micron (No. 100), and 74-micron (No. 200) sieves, conforming to the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3]

SAMPLING

Time of Sampling

3. The coal shall be sampled when it is being loaded into or unloaded from railroad cars, ships, barges, or wagons, or when discharged from supply bins, or from industrial railway cars, or grab buckets, or from any coal-conveying equipment, as the case may be. It is not feasible to collect representative samples for screen analysis from the surface of coal in piles or from loaded cars or bins.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-5 on Coal and Coke.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1242.

[3] *Ibid.*, p. 1244.

Collection of Gross Sample

4. Increments shall be regularly and systematically collected, so that the entire quantity of coal sampled will be represented proportionately in the gross sample, and with such frequency that a gross sample of the required amount shall be collected. The number of increments collected shall be not less than 20. When the coal is passing over a conveyor or down a chute, increments the full width and thickness of the stream of coal shall be taken either by stopping the conveyor and removing all coal from a transverse section of it or by momentarily inserting a suitable container into the stream. If it is impracticable to collect increments the full width and thickness of the coal stream, increments shall be systematically collected from all portions of the stream.

Weight of Gross Sample

5. The weight of the gross sample collected shall conform to the following:

Run-of-mine coal	not less than 4000 lb.
Screened coal with upper limit larger than 4-in. round	not less than 4000 lb.
Coal smaller than 4-in. round	not less than 2000 lb.
Coal smaller than 2-in. round	not less than 1000 lb.
Coal smaller than 1-in. round	not less than 500 lb.
Coal smaller than $\frac{1}{2}$-in. round	not less than 100 lb.

Reduction of Gross Sample

6. Reduction of the quantity of the gross sample shall conform to the following:

(*a*) *Coal Larger than 1-in. Round.*—Coal larger than 1-in. round shall be screened without mixing or reducing.

(*b*) *Coal Smaller than 1-in. Round.*—Coal smaller than 1-in. round may be reduced in amount to not less than 125 lb. by riffling or by arranging it in a long, flat pile and successively halving it or quartering it by the alternate-shovel method as follows: Take successive shovelfuls in passing around the pile (advancing a distance equal to the width of the shovel for each shovelful), and retain alternate shovelfuls or every fourth shovelful for the sample.

(*c*) *Coal Smaller than $\frac{1}{2}$-in. Round.*—Coal smaller than $\frac{1}{2}$-in. round may be reduced to not less than 25 lb. by passing it through a riffle or equally accurate reducing device, or by hand-quartering as described in the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21) of the American Society for Testing Materials.[1]

(*d*) *Coal Smaller than No. 4 Sieve.*—Coal smaller than the No. 4 sieve may be reduced to not less than 2 lb. by riffling or hand-quartering.

(*e*) *Coal Smaller than No. 8 Sieve.*—Coal smaller than the No. 8 sieve may be reduced to not less than 1 lb. by riffling or hand-quartering.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 318.

PROCEDURE

Drying Sample

7. In case the coal is wet, the sample may be tested on screens 1-in. round and larger without drying, but the sample of coal smaller than 1-in. round (reduced in amount to 125 lb., as described in Section 6 (*b*), shall be dried sufficiently to remove surface moisture which causes small particles to cling to the larger pieces. In cases of lignite, subbituminous, and high volatile C bituminous coals, care shall be observed not to over dry and cause weathering of the coal.

Screen Analysis

8. The sample shall be accurately weighed before screening. Starting with the largest gage-ring or screen, the sample shall be screened in such increments as will allow the pieces to be in direct contact with the openings at the completion of the screening of each increment. The smallest screen through which all the sample passes shall be determined by actual test, in accordance with the following Paragraphs (*a*) to (*c*):

(*a*) *Coal Larger than 2½-in. Round.*—Pieces of coal not passing readily through screens 2½-in. round and larger shall be tried by hand to see if they will pass through the openings in any position. Screens 2½-in. round and larger shall not be shaken except for whatever jiggling may be necessary to clear the screens of fine coal.

(*b*) *Coal Smaller than 2½-in. Round.*—Coal passing the 2½-in. round screen shall be tested with screens down to and including 1-in. round as follows: The screen shall be moved horizontally a distance of about 8 in. at just sufficient rate to cause the pieces of coal to tumble or roll on the screen. The motion of the screen shall be stopped without impact. After 10 such shakes (5 in each direction), screening of the increment shall be considered complete.

(*c*) *Coal Smaller than 1-in. Round.*—Coal passing the 1-in. round and smaller screens may be weighed and then reduced in amount as provided in Section 6 and then shall be dried as provided in Section 7. Screens smaller than 1-in. round shall be shaken gently with a reciprocating horizontal motion until practically no more coal will pass through the openings. When both No. 100 and No. 200 sieves are used, the latter shall be used first in order to facilitate screening.

Report

9. (*a*) The screen analysis results shall be reported to the nearest 0.1 per cent as follows:

	PER CENT
Retained on .... in. round	0
Retained on .... in. round, passing .... in. round	....
....	....
....	....
....	....
Retained on No. ...., passing .... in. round	....
Retained on No. ...., passing No.	....
Passing No.	....

(*b*) If the sum of the weights shows a loss of over 2 per cent, the analysis shall be rejected and another test made.

TENTATIVE DEFINITIONS OF THE TERMS GROSS CALORIFIC VALUE AND NET CALORIFIC VALUE OF FUELS[1]

A.S.T.M. Designation: D 407 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Gross Calorific Value, H_s.—In the case of solid fuels and liquid fuels of low volatility, the heat produced by combustion of unit quantity, at constant volume, in an oxygen bomb calorimeter under specified conditions.

Note.—The conditions are initial oxygen pressure of 20 to 40 atmospheres, final temperature of 68 to 95 F. (20 to 35 C.), products in form of ash, liquid water, and gaseous CO_2, SO_2 and nitrogen. This definition is not applied to gaseous or highly volatile liquid fuels.

Net Calorific Value, H_i.—In the case of solid fuels and liquid fuels of low volatility, a lower value calculated from the gross calorific value as the heat produced by combustion of unit quantity, at constant atmospheric pressure, under conditions such that all water in the products remains in the form of vapor.

Note.—The net calorific value is calculated from the gross calorific value by making a deduction of 1020 B.t.u. per lb. (567 cal. per g.) of water derived from unit quantity of fuel, including both the water originally present as moisture and that formed by combustion. The deduction is not equal to the latent heat of vaporization of water (1050 B.t.u. per lb. at 75 F. (24 C.)) because the calculation is made to reduce from gross value at constant volume to net value at constant pressure, for which the correct factor is 1020 B.t.u. per lb.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee D-5 on Coal and Coke.

TENTATIVE SPECIFICATIONS
FOR
TIMBER PILES[1]

A.S.T.M. Designation: D 25 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1915; ADOPTED, 1920; REISSUED AS TENTATIVE IN AMENDED FORM, 1930; REVISED, 1934, 1935.

Scope

1. These specifications cover requirements for round timber piles to be used untreated, or treated by standard preservatives. Where sawed timber is used as piling, such as heavy sheet piles, appropriate specifications should be selected from the Standard Specifications for Structural Wood Joist and Planks, Beams and Stringers, and Posts and Timbers (A.S.T.M. Designation: D 245) of the American Society for Testing Materials.[2]

Kinds of Wood

2. (*a*) The purchaser shall specify the kind or kinds of wood he desires to use, and shall designate the kinds he desires for preservative treatment. Commonly used species are cedars, chestnut, cypress, Douglas fir, larch, oaks, pines, spruces, and tamarack.

(*b*) Piles of different kinds of wood shall be delivered in separate lots.

Use Classification

3. Timber piles are classified in these specifications under three general divisions according to the use intended, as follows:

(*a*) *Class A.*—Class A piles are suitable for use in heavy railway bridges and trestles. The minimum diameter of butt assumes the use of load-bearing timber caps 14 in. in width.

(*b*) *Class B.*—Class B piles are suitable for use in docks, wharves, highway work and general construction. The minimum diameter of butt assumes the use of load-bearing timber caps 12 in. in width.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-7 on Timber.

These specifications are in effect a revision of the former Standard Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted (A.S.T.M. Designation: D 25 – 20), which standard was accordingly discontinued in 1930.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 347.

When timber caps are not used, as in the case of piles under masonry foundations, the sizes given for Class C piles are recommended.

(*c*) *Class C.*—Class C piles are suitable for use in foundations which will always be completely submerged, for coffer-dams, falsework, and sundry temporary work.

Class A and Class B Piles

General Quality

4. Except as hereinafter provided, Class A and Class B piles shall be free from any defects which may impair their strength or durability as piling, such as decay, red heart, splits in piles to be treated, or splits longer than the measured butt diameter of piles not to be treated, twist of grain exceeding one-half of the circumference in any 20 ft. of length, unsound knots, numerous knots or holes, or shake more than one-third of the diameter of the pile. Piles which have been scored for turpentine shall be accepted, provided such scar does not exceed 36 in., and provided the scoring is of recent date showing the scar to be entirely sound and free from insect damage.

Knots

5. Sound knots will be permitted in Class A and Class B piles, provided they are not in clusters. The diameter of a sound knot shall not be greater than one-third of the minimum diameter of the pile at the section where it occurs, and shall not exceed 4 in. for piles 50 ft. and under in length. For piles over 50 ft. in length, knots between the section at mid-length and the butt shall conform to the limitation prescribed for piling under 50 ft. Between mid-length and the tip, single knots up to 5 in. in diameter will be permitted, provided they do not exceed one-half the minimum diameter of the pile at the section where they occur. The diameter of a knot shall be measured at right angles to the length of the pile.

General Requirements

6. (*a*) *Sound Timber.*—Class A and Class B piles shall be cut from sound, live trees, except that fire-killed, blight-killed, or wind-felled timber may be used if not attacked by decay or insects. Piles shall be cut above the ground swell.

(*b*) *Tip.*—The tip shall be sound.

(*c*) *Butt End.*—The butt end shall be sound except in cedar piles, which may have a pipe or stump rot hole not more than $1\frac{1}{2}$ in. in diameter.

(*d*) *Taper.*—Piles shall have a gradual taper from the point of butt measurement to the tip.

(*e*) *Surface Finish.*—All knots and limbs shall be trimmed or smoothly cut flush with the surface of the pile. Butt and tip shall be sawed square with the axis of the pile, or tip may be tapered to a point not less than 4 in. in diameter if directed by the engineer in charge.

Sapwood

7. (*a*) *Piles for Use Untreated.*—Piles for use without preservative treatment shall have as little sapwood as possible, and when used in exposed work, the diameter of the heartwood shall not be less than eight-tenths of the actual diameter of the pile at the butt.

TABLE I.—DIAMETERS OF THREE CLASSES OF PILES.

Length, ft.	Class A and Class B Piles (These differ in size only.)						Class C Piles[a] (These differ from Classes A and B in size and quality.)		
	Class A			Class B					
	Diameter 3 ft. from Butt, in.		Minimum Diameter of Tip, in.	Diameter 3 ft. from Butt, in.		Minimum Diameter of Tip, in.	Diameter 3 ft. from Butt, in.		Minimum Diameter of Tip, in.
	Minimum	Maximum		Minimum	Maximum		Minimum	Maximum	
DOUGLAS FIR AND SOUTHERN PINE PILES[b]									
Under 40	14	18	10	12	20	8	12	20	8
40 to 50, incl	14	18	9	12	20	7	12	20	6
51 to 70, incl	14	18	8	13	20	7	12	20	6
71 to 90, incl	14	20	7	13	20	6	12	20	6
Over 90	14	20	6	13	20	5	12	20	5
BLACK OAK, CHESTNUT, CYPRESS, PIN OAK, POST OR BURR OAK, RED OAK, WHITE OAK, OR WILLOW OAK PILES									
Under 30	14	18	10	12	18	8	12	20	8
30 to 40, incl	14	18	9	13	20	8	12	20	8
Over 40	14	18	8	13	20	7	12	20	6
CEDAR PILES									
Under 30	14	22	10	12	22	8	12	22	8
30 to 40, incl	14	22	9	13	22	8	12	22	8
Over 40	14	22	8	13	22	7	12	22	7

[a] In Class C piles a minimum diameter (at cut-off) of 10 in. may be specified for lengths of 20 ft. and under.

[b] Where larch, lodgepole or Norway pine, spruce, or tamarack piles are specified, their dimensions shall correspond to the requirements shown for Douglas fir and southern pine.

(*b*) *Piles for Treatment.*—Piles for use with preservative treatment shall have no sapwood restrictions, but preferably shall contain as much sapwood as possible. In southern pine the sapwood thickness shall not be less than 1½ in. and in Douglas fir and larch not less than 1 in. on the butt end.

Peeled Piles

8. (*a*) Piles shall be peeled of bark, including the inner skin, soon after cutting so that the piles are smooth and clean. Care shall be taken to remove as little sapwood as possible while peeling the bark. The sapwood shall not be injured by unnecessary axe cuts. These piles shall be designated as piles for treatment.

(*b*) No pile shall be considered as thoroughly peeled unless all of the rough bark and at least 80 per cent of the inner bark which remains on the pile shall have been removed. In no case shall any piece of inner bark be over $\frac{3}{4}$ in. in width or over 8 in. in length, and there shall be 1 in. of clean wood surface between any two strips of inner bark.

Diameter

9. (*a*) It is recommended that the diameters of piles measured under the bark shall conform to the requirements shown in Table I, subject to a permissible variation of $-\frac{1}{2}$ in. in any diameter in not more than 25 per cent of the piles of that diameter.

(*b*) The diameter of a pile in cases where the tree is not exactly round shall be determined either by measuring the circumference and dividing the number of inches by 3.14, or by taking the average of the maximum and minimum diameters at the location specified.

Length

10. All piles shall be furnished on order cut to any of the following lengths: 16 to 40 ft. in multiples of 2 ft., and over 40 ft. in multiples of 5 ft. A variation of 6 in. in length shall be allowable, but the average length in any shipment shall be equal to, or greater than, the specified lengths. The length of each pile shall be legibly marked on the butt end with white or black paint.

Straightness

11. Piles shall be free from short or reversed bends, and free from crooks greater than one-half of the diameter of the pile at the middle of the bend. In short bends, the distance from the center of the pile to a line stretched from the center of the pile above the bend to the center of the pile below the bend shall not exceed 4 per cent of the length of the bend, or $2\frac{1}{2}$ in. A line drawn from the center of the butt end to the center of the tip shall lie within the body of the pile.

Class C Piles

General Quality

12. Class C piles shall be of sound, live timber that will stand driving, and need not be peeled if they are to be used without preservative treatment. They shall be free from decay and other imperfections such as bad knots and shakes which will materially affect their strength. Piles which have been scored for turpentine shall be accepted, provided such scar does not exceed 36 in., and provided the scoring is of recent date showing the scar to be entirely sound and free from insect damage.

General Requirements

13. (*a*) *Tip.*—The tip shall be sound.

(*b*) *Taper.*—Piles shall have a gradual taper from the point of butt measurement to the tip.

(*c*) *Surface Finish.*—All knots and limbs shall be trimmed or smoothly cut flush with the surface of the pile. Butt and tip shall be sawed square with the axis of the pile, or tip may be tapered to a point not less than 4 in. in diameter if directed by the engineer in charge.

Sapwood

14. Sapwood requirements shall be identical with those for Class A and Class B piles as specified in Section 7.

Peeled Piles

15. The requirements for peeled piles shall be identical with those for Class A and Class B piles as specified in Section 8.

Diameter

16. The methods of measurement of diameter and the permissible variations in diameter shall be identical with those for Class A and Class B piles as specified in Section 9. The recommended sizes are given in Table I.

Length

17. The requirements for length shall be identical with those for Class A and Class B piles as specified in Section 10.

Straightness

18. The requirements relating to straightness shall be identical with those for Class A and Class B piles as specified in Section 11.

TENTATIVE SPECIFICATIONS
FOR
BLUE LEAD; BASIC SULFATE[1]

A.S.T.M. Designation: D 405 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These specifications cover blue lead, basic sulfate, suitable for use in paints. It may be purchased in the dry form or ground in oil to form a paste.

Composition and Properties

2. (*a*) *Dry Pigment.*—The pigment shall consist of basic lead sulfate and certain other ingredients, which upon analysis shall meet the following requirements:

	MAXIMUM	MINIMUM
Lead sulfate, per cent	....	45.0
Lead oxide, per cent	....	30.0
Lead sulfide, per cent	12.0	....
Lead sulfite, per cent	5.0	....
Zinc oxide, per cent	5.0	....
Carbon and undetermined, per cent	5.0	....
Coarse particles (total residue retained on a No. 325 sieve[2]), per cent	1.0	....

(*b*) *Paste in Oil.*—The paste in oil shall be made by thoroughly grinding the pigment with linseed oil to a paste consistency. The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions without curdling, with linseed oil, turpentine, or volatile petroleum spirits or any mixture of these substances.

The paste shall conform to the following requirements:

	MAXIMUM	MINIMUM
Pigment, per cent	....	89.0
Linseed oil, per cent	11.0	....
Moisture and other volatile matter, per cent	0.7	....
Coarse particles and skins (total residue retained on a No. 325 sieve[2]), per cent of the dry pigment	1.5	....

Number of Tests

3. One sample shall be taken at random from each lot of 1000 packages or fraction thereof. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

[2] For determining coarse particles, sieves 3 in. in diameter are recommended, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, see 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

TENTATIVE METHOD OF TEST
FOR
COMPARATIVE HIDING POWER OF WHITE PIGMENTS[1]

A.S.T.M. Designation: D 406 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method is intended for determining the hiding power of white pigments and is only to be used for a comparison of standard and sample of the same type of white pigment.

Hiding Power, Definition

2. The definition of hiding power as it appears in the Standard Definitions of Terms Relating to Paint Specifications (A.S.T.M. Designation: D 16) of the American Society for Testing Materials is as follows:

Hiding Power.—The power of a paint or paint material as used to obscure a surface painted with it.

NOTE.—In this definition the word "obscure" means to render invisible or to cover up a surface so that it cannot be seen.

Apparatus

3. The apparatus shall consist of the following:

(*a*) *Balance.*—Regulation laboratory balance, sensitive to at least 0.1 g.

(*b*) *Burette.*—Standard 1-ml. burette, graduated in 0.1 ml., (stop-cock controlled) or the apparatus known as the Brown burette, which consists of a small burette as just described but with a small reservoir. The tips of all burettes shall be ground optically flat.

(*c*) *Glass Mullers.*—Standard type glass mullers with a grinding face of from $2\frac{3}{4}$ to 3 in. in diameter. The face shall be free from blowholes and other imperfections, and kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine. The edge should be beveled.

(*d*) *Rubbing Surface.*—Lithographers' stones or ground plate glass slabs, the surface of which is kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

(*e*) *Spatula.*—A flexible spatula having a 6-in. blade for mixing the oil and pigment.

(*f*) *Paint Brush.*—A 1-in. paint brush of good grade.

(*g*) *Painting Surface.*—A fairly smooth impervious surface of approximately 1 sq. ft. composed of alternate gray (approximately 40 per cent brightness) and white (approximately 75 per cent brightness) areas.

(*h*) *Paint Container.*—Either a 50-ml. laboratory beaker or a $\frac{1}{8}$-pt. paint can.

(*i*) *Illumination.*—A means of obtaining constant illumination preferably approximating northern sky light.

Materials

4. The following materials will be required:

(*a*) *Standard Pigment.*—A standard white pigment mutually agreed upon by the seller and purchaser. The specific gravity of the standard pigment shall be approximately the same as that of the sample.

(*b*) *Oil.*—Alkali-refined linseed oil, of low acid value, heat bodied (575 F. (301 C.), approximately 1 hr.) to a viscosity of E to F on the Gardner-Holdt scale (sp. gr. approximately 0.94). The oil is used without thinner.

Procedure

5. The hiding power of white pigments shall be determined as follows:

(*a*) Weigh accurately the amount of standard white pigment indicated by the following table and measure out the corresponding quantity of oil required for mulling:

PIGMENT	WEIGHT OF PIGMENT PER SINGLE MULLING, G.	AMOUNT OF OIL PER SINGLE MULLING, ML.	TOTAL AMOUNT OF ADDITIONAL OIL TO PRODUCE 30 ML. OF BRUSHABLE PAINT (TO BE ADDED TO 2 MULLINGS), ML.
White lead	25.5	4.0	14.5
Zinc oxide	17.0	5.3	13.5
35 per cent leaded zinc oxide	22.3	4.8	13.0
Antimony oxide	21.5	6.8	9.0
Lithopone	16.2	6.8	9.0
High strength lithopone	15.8	6.8	9.0
Zinc sulfide	15.0	6.8	9.0
Titanium barium pigment	16.2	6.8	9.0
Titanium calcium pigment	11.8	6.8	9.0
Titanated lithopone	15.8	6.8	9.0
Titanium dioxide	11.8	7.3	9.5

(*b*) Place the materials on the rubbing slab and work them into a paste with the spatula. Then rub up the paste with the glass muller, using a stroke 3 to 4 in. in width and from 12 to 15 in. in length. In counting rubs, one stroke up and one stroke back is considered one rub. Allow the muller to travel up one side and back the other side, twisting the muller slightly at the top and bottom of each half stroke to help work in the pigment. After each 25 rubs with the muller "pick up" the pigment with the spatula by scraping the face of the muller and gathering the paste on the slab into a daub. Continue the mulling until the paste is given 100 rubs. Two such quantities of paste are to be produced by mulling. To the two paste preparations add the amount of additional oil required for brushing consistency as specified in the table in Paragraph (*a*). Mix this oil with the paste by means of the spatula. Then transfer the entire amount of paint to the beaker. Weigh the brush and paint. Apply the paint to the painting surface in a smooth, uniform film until no difference in brightness, when viewed normally, can be detected between the gray and white areas. Weigh again the sample (beaker, paint and brush). Record the difference in weight as a measure of the hiding power of the pigment.

(*c*) Treat the sample of pigment to be measured in the same manner as the standard. To be satisfactory in hiding power, the number of grams of pigment in oil dispersion required by the unknown shall be no more than that required by the standard.

TENTATIVE METHOD OF TEST
FOR
TINTING STRENGTH OF WHITE PIGMENTS OR WHITE PIGMENT PASTES[1]

A.S.T.M. Designation: D 332 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1931; REVISED, 1934, 1935.

Scope

1. This method is intended for determining the tinting strength of white pigments or white pigment pastes and is only to be used for a comparison of standard and sample of the same type of white pigment.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—Regulation laboratory balance, sensitive to at least 1 mg.

(*b*) *Burettes.*—Standard 1-ml. burettes, graduated in 0.1 ml., (stopcock controlled) or the apparatus known as the Brown burette, which consists of a small burette as just described but with a small reservoir. The tips of all burettes shall be ground optically flat.

(*c*) *Glass Mullers.*—Standard type glass mullers with a grinding face of from 2¾ to 3 in. in diameter. The face shall be free from blow-holes and other imperfections, and kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine. The edge should be beveled.

(*d*) *Rubbing Surface.*—Lithographers' stones or ground plate glass slabs, the surface of which is kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine.

(*e*) *Glass or Celluloid Sheets.*—Sheets of flat glass or flexible celluloid for use in weighing out the oils and pastes.

(*f*) *Spatula.*—A flexible spatula having a 3-in. blade for mixing the oil and pigment.

(*g*) *Scraper.*—A French scraper or body glazing scraper for smoothing down the color daubs. The scraper shall have a blade that is about 3 or 4 in. in width with a good straight edge.

(*h*) *Panels.*—Bright tin or clear glass panels for use in observing color matches.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

Materials

3. The following materials will be required:

(*a*) *Standard Pigment or Paste.*—A standard white pigment or white pigment paste mutually agreed upon by the seller and purchaser.

(*b*) *Tinting Material.*—Either ultramarine blue or a very fine, low-strength, uniform black tinting material prepared from finest lampblack (Note 1). If desired, the tinting material, either ultramarine blue or black, may be prepared in the form of an oil paste (Note 2) ground fine and placed in small collapsible tubes.

NOTE 1.—It is advisable to prepare such a pigment from the finest lampblack and the finest precipitated calcium carbonate by intimate mixing of one part of the dry lampblack and six parts of the dry calcium carbonate until a uniform mixture is obtained which will give check results with several duplicate samples of a standard white pigment.

NOTE 2.—Recommended formulas for such a paste using ultramarine blue are as follows:

140 lb. Ultramarine blue	70 lb. Ultramarine blue
50 lb. Poppy oil	27 lb. Refined linseed oil
3 lb. Calcium stearate	3 lb. 4-hr. cooked linseed oil (560 F.)
2 lb. Castile soap	
½ lb. Turpentine	

(*c*) *Oil.*—White refined linseed oil with an acid number of approximately 4. The use of bodied oils or varnish may be essential in some cases.

Tinting Strength, White Pigments

4. The tinting strength of white pigments shall be determined as follows:

(*a*) Weigh accurately 2 g. of the standard white pigment and the amount of ultramarine blue or lampblack and measure the amount of oil as indicated in the following table:

Pigment	Weight of Pigment, g.	Amount of Oil, ml.	Weight of Tinting Material, g. Ultramarine Blue	Weight of Tinting Material, g. Lampblack
White lead	2	0.4	0.2	0.04
Zinc oxide	2	0.6	0.2	0.04
Zinc oxide (35 per cent leaded)	2	0.4	0.2	0.04
Lithopone	2	0.5	0.2	0.04
Extra strength lithopone	2	0.5	0.2	0.04
Zinc sulfide	2	0.6	0.4	0.08
Titanium barium pigment	2	0.5	0.2	0.04
Titanium calcium pigment	2	0.5	0.2	0.04
Titanium dioxide	2	0.9	0.4	0.08

Use sheets of flat glass or flexible celluloid in weighing out the pigments, oils and pastes. For regular control work, the use of the burette is recommended for measuring the oil used, instead of weighing, because of the simplicity, speed and tolerant accuracy of the burette. Be sure to allow sufficient time for the burette to drain to its true level. In case of doubt or dispute over any tint or in the case of viscous oils, all portions shall be weighed. If desired, the tinting material may be added in the form of a paste and in this case the weighed quantity of paste shall have the amount of tinting material specified in the above table, and shall be added to the mulled sample on the rubbing slab and thoroughly mixed with the spatula until no streaking is noticeable. Place the materials on the rubbing surface and work them into a paste with the spatula, then rub up the paste with the glass muller, using a stroke 3 to 4 in. in width and from 12 to 15 in. in length. In counting rubs, one stroke up and one stroke back is considered one rub. Allow the muller to travel up one side and back the other side, twisting the muller slightly at the top and bottom of each half stroke to help work in the pigment. After each 25 rubs with the muller, "pick up" the pigment with the spatula by scraping the face of the muller and gathering the paste on the slab into a daub. Continue the mulling until the paste is given 100 rubs.

(*b*) Treat 2 g. of the unknown sample of white pigment in exactly the same manner as prescribed in Paragraph (*a*) for the standard white pigment, using the same amount of tinting material and oil. Give the sample 100 rubs. Place the unknown and standard samples in juxtaposition on a bright tin or clear glass panel. Make the daub of each sample about 1 in. in width and 2 in. in length and draw the scraper lightly over the pastes to even off the ridge and so place both daubs on an even plane. If glass is used, the rub-outs may be observed either from the top or through the glass panel.

(*c*) If the unknown sample differs appreciably from the standard sample in tint, other pastes of the standard white pigment may be prepared, using various amounts of the tinting material to give a series of standards. The unknown sample of white pigment shall then be compared with the series of rub-outs of the standard pigment, the quality of tint being judged by placing the rub-outs in juxtaposition on the tin or glass panel as in the procedure described in Paragraph (*b*).

Calculation

5. The tinting strength of the unknown sample shall be calculated as follows:

$$\text{Tinting strength of pigment} = \frac{\text{Wt., in grams, of tinting material used with standard sample to give equality of tint}}{\text{Wt., in grams, of tinting material used with unknown sample}} \times T$$

where T = the empirical tinting strength value given to the standard white pigment.

Optional Procedure

6. (*a*) The method described in Sections 4 and 5 is satisfactory for routine testing of samples of white pigments of the kind which do not vary greatly in tinting strength. Variations in the brightness or consistency of

the tinted pastes used for matching cause variations in the relative tinting strength of the samples being tested. When comparing similar pigments which do not vary greatly in tinting strength, these errors are negligible but when comparing pigments which do vary greatly in tinting strength; the comparison should best be made with tinted pastes of standard brightness and standard consistency. In the following method all comparisons shall be made with pastes that have a brightness or light reflection of 20 per cent and equal consistency.

(*b*) Weigh accurately 2 g. of the standard white pigment and a sufficient amount of the blue (or black) tinting material to produce a paste which will have a 20 per cent light reflection (Note 1) when mixed with oil. Place these materials on the rubbing surface and add sufficient oil to produce a paste of medium consistency (Note 2). Mull the sample as described in Section 4 (*a*) until the paste is given 100 rubs.

NOTE 1.—The light reflection may be measured by the Marten's photometer or other suitable instrument or by comparison with a paste known to have the specified light reflection.

NOTE 2.—This consistency shall be such that the paste can just be thrown from the spatula by a gentle whipping motion of the hand or by the tapping of the spatula blade with the index finger.

(*c*) Treat 2 g. of the unknown sample of the white pigment in exactly the same manner as described in Paragraph (*b*) for the standard white pigment, using sufficient tinting material to produce a paste which will exactly match the standard paste. Use sufficient oil with the unknown sample of white pigment to produce a paste having approximately the same consistency as the standard paste. Give the sample 100 rubs as described in Section 4 (*a*). It will be necessary to prepare several 2-g. portions of the unknown sample of white pigment using various amounts of the tinting material until the color of the standard paste is exactly matched. Judge the color match as described in Section 4 (*b*).

Calculation (Optional Procedure)

7. The tinting strength of the unknown sample shall be calculated from the following formula:

$$\text{Tinting strength of pigment} = \frac{\text{Wt., in grams, of tinting material used with unknown sample to give equality of tint}}{\text{Wt., in grams, of tinting material used with standard sample}} \times T$$

where T = the empirical tinting strength value given to the standard white pigment.

Tinting Strength, Pastes

8. When the sample is in paste form, the tinting material should also preferably be in the form of an oil paste. The weighed quantity of tinting

material in paste form shall be added to the weighed sample of white pigment paste on the rubbing slab and thoroughly mixed with the spatula until no streaking is noticeable. The tinting strength shall then be determined in accordance with the procedure described in Section 4 (*b*) and the calculation made as in Section 5. If desired, the optional procedure in Section 6 (*c*) may be used and the calculation made as in Section 7.

TENTATIVE METHODS OF TEST
FOR
MASS COLOR AND TINTING STRENGTH OF DRY COLOR PIGMENTS OR PASTES[1]

A.S.T.M. Designation: D 387 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1934; Revised, 1935.

Scope

1. These methods are intended for determining the mass color and tinting strength of the materials generally known as dry colors, either in the form of dry pigments or in the form of pastes in oil or Japan. They do not apply to the white pigments.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—Regulation laboratory balance, sensitive to at least 1 mg.

(*b*) *Burettes.*—Standard 1-ml. burettes, graduated in 0.1 ml., (stop-cock controlled) or the apparatus known as the Brown burette, which consists of a small burette as just described but with a small reservoir. The tips of all burettes shall be ground optically flat.

(*c*) *Glass Mullers.*—Standard type glass mullers with a grinding face of from $2\frac{3}{4}$ to 3 in. in diameter. The face shall be free from blow-holes and other imperfections, and kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine. The edge should be beveled.

(*d*) *Rubbing Surface.*—Lithographers' stones or ground plate glass slabs, the surface of which is kept sharp by lightly grinding with No. 303 optical emery or its equivalent and turpentine. To guard against contamination, different slabs or stones should be available for red, yellow, blue, green and black pigments.

(*e*) *Glass or Celluloid Sheets.*—Sheets of flat glass or flexible celluloid for use in weighing out the samples of dry colors, oils and pastes.

(*f*) *Spatula.*—A flexible spatula having a 3-in. blade for mixing the oil and pigment.

(*g*) *Scraper.*—A French scraper or body glazing scraper for smoothing down the color daubs placed on the glass or tin panels.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

The scraper shall have a blade that is about 3 or 4 in. in width with a good straight edge.

(*h*) *Panels.*—Bright tin or clear glass panels for use in observing color matches.

Materials

3. The following materials will be required:

(*a*) *Standard Pigment or Paste.*—A standard pigment (dry color) or paste color in oil or Japan mutually agreed upon by the seller and purchaser.

(*b*) *Reduction Paste.*—Zinc oxide oil paste for tinting strength test (Note).

Note.—Recommended formulas for such a paste are as follows:

No. 1[a]	300 lb. Green seal zinc oxide 64 lb. Poppy oil 2 lb. Calcium stearate 1 lb. Turpentine
No. 2[b]	90 lb. Green seal zinc oxide 10 lb. Refined linseed oil 1 lb. 4-hr. cooked linseed oil (560 F.)
No. 3[b]	100 lb. Green seal zinc oxide 25 lb. Heat bodied oil (of "O" Litho varnish consistency)

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[a] This formula yields a short paste, handy to use and which has little tendency to settle. The paste should be ground fine and placed in small collapsible tubes.

[b] This formula yields a paste that is slightly stringier than No. 1 and settles very little. New oil pastes should be prepared at least once each month. The paste should be ground fine and placed in small collapsible tubes.

(*c*) *Oil.*—White refined linseed oil with an acid number of approximately 4. In special cases, other oils may be essential, for example, earth colors may require raw oil, or pigments for printing inks require transparent lithographic varnish. Such special oils should be arranged for by the seller and purchaser.

Mass Color

4. Mass color shall be determined as follows:

(*a*) Carefully weigh the sample of pigment to be tested and counterbalance with the standard pigment. For regular control work the use of the burette is recommended for measuring the oil used, instead of weighing, because of the simplicity, speed and tolerant accuracy of the burette. In case of doubt and dispute over any color, or in the case of viscous oils, all portions shall be weighed. If oil is to be weighed, add oil to the dry samples accurately. Transfer the oil and pigment to the rubbing slab. If oil is to be measured, transfer the weighed samples of the pigments to the slab and add oil by dropping (slowly) from the burette, working up the paste with the small spatula. Be sure to allow sufficient time for the burette to drain to its true level. When all the dry pigment is worked up by means of the spatula, rub up the paste with the glass muller. Use a stroke from 3 to 4 in. in width and from 12 to 15 in. in length. In counting rubs given a color, one stroke up and one stroke back is considered one rub. Allow the muller to travel up one side and back the other side, twisting the muller slightly at the top and bottom of each half stroke to help work in the pigment. After the number of rubs with the muller, as specified in the following table, depending on the type of pigment, "pick up" the paste with the spatula by scraping the face of the muller and gathering the paste on the slab into a daub. Continue the mulling until the paste is given the specified number of rubs:

TOTAL NUMBER OF RUBS REQUIRED FOR PIGMENT	PICK-UP REQUIRED
300	after each 50 rubs
200	after each 40 rubs
150	after each 30 rubs
100	after each 25 rubs
80	after each 20 rubs
60	after each 15 rubs

(*b*) When the mulling is completed, place the unknown and standard samples in juxtaposition on the bright tin or clear glass panel. Make the daub of each sample about 1 in. in width and 2 in. in length and draw the scraper lightly over the pastes to even off the ridges and so present both daubs on an even plane. Mass tone should be judged immediately. If glass is used observe the rub-outs from the top and not through the glass panel. A pigment shall be considered as passing this test when its mass color is the same as that of the mutually agreed upon standard.

NOTE.—Where higher precision is required than that afforded by visual examination or where it is desirable to determine the color characteristics of the material in terms of fundamental physical units, this may be done by use of the Standard Method of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (A.S.T.M. Designation: D 307) of the American Society for Testing Materials.[1]

Tinting Strength, Color Pigments

5. The tinting strength of color pigments shall be determined as follows:

(*a*) Weigh the required amount of the mulled color paste from the slab and counterbalance with the standard pigment. Then add the correct amount of the "Reduction Paste" (zinc oxide oil paste) to the unknown and standard samples. Thoroughly mix each of the pastes on the flat glass or flexible celluloid sheets and transfer samples to the slab, mixing them thoroughly with spatula only, till no more streaking is noticeable.

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[1] 1933 Book ofA.S.T.M. Standards, Part II, p. 731.

(*b*) Place the unknown and standard samples in juxtaposition on the bright tin or clear glass panel. Make the daub of each sample at least 1 in. in width and about 2 in. in length and draw the scraper lightly over the pastes to even off the ridge and so present both daubs on an even plane. Judge the color immediately. If glass is used, observe the rub-outs from the top and not through the glass panel. If the sample shows the same character of tint and the rub-out is as dark or darker than the standard, it meets this test for tinting strength.

Note 1.—The following pigment rub-out scheme is outlined for the convenience of the operator. Because of the difference in oil absorption of similar pigments made by different manufacturers, the pigment rub-out scheme can necessarily serve only as a guide in the work.

PIGMENT RUB-OUT SCHEME

COLOR OR CLASS	AMOUNT OF COLOR, G.	VOLUME OF OIL, ML.	MULLS OR RUBS	REDUCTION, GRAMS OF REDUCTION PASTE TO GRAMS OF MULLED PASTE
C. P. Iron blues	1.0	0.80	300	5 to 0.1
C. P. Light and medium para toners	0.5	0.80	200	5 to 0.1
C. P. Dark para toners	0.6	0.80	300	5 to 0.1
10 per cent Para toners on whiting	1.0	0.50	60	2 to 0.1
C. P. Toluidine	0.5	0.50	150	5 to 0.1
C. P. Light chrome green	1.0	0.40	100	2 to 0.1
C. P. Medium chrome green	1.0	0.50	150	2 to 0.1
C. P. Deep chrome green	1.0	0.60	200	2 to 0.1
25 per cent Grinder's green, light	1.0	0.30	60	2 to 0.1
25 per cent Grinder's green, medium	1.0	0.40	60	2 to 0.1
25 per cent Grinder's green, deep	1.0	0.40	80	2 to 0.1
C. P. Chromium oxide	2.0	0.40	60	2 to 0.1
C. P. Primrose chrome yellow	1.0	0.20	60	2 to 0.1
C. P. Light chrome yellow	1.0	0.50	60	2 to 0.1
C. P. Medium chrome yellow	1.0	0.30	60	2 to 0.1
C. P. Dark chrome yellow	2.0	0.40	60	2 to 0.1
C. P. Zinc yellow	1.0	0.40	60	2 to 0.1
English vermillion	2.0	0.50	100	2 to 0.1
Ultramarine blue	1.0	0.50	150	2 to 0.1
Cobalt blue	1.0	0.50	150	2 to 0.1
High strength carbon black	0.3	2.80	150	5 to 0.1
Bone black	1.0	0.80	100	2 to 0.1
Lampblack	0.3	1.00	100	5 to 0.1
Carbon black	0.3	1.30	150	5 to 0.1
Ferrite yellow	0.5	0.30	100	2 to 0.1
French yellow ochre	1.0	0.55	100	2 to 0.1
Light red oxide	1.0	0.70	100	2 to 0.1
Indian, Spanish, Venetian, Persian Gulf oxides and metallic brown	1.0	0.40	100	2 to 0.1
Raw and burnt sienna	1.0	0.60	100	2 to 0.1
Raw and burnt umber	1.0	0.80	100	2 to 0.1

NOTE 2.—In many cases, the paint manufacturer producing industrial, freight car, marine, barn or anti-corrosive paints is interested in wetting the pigment with the vehicle. Such methods of grinding in oil do not reduce the particle size or develop additional tinctorial value of the pigment. The covering power of such paints is therefore dependent upon the degree to which the color manufacturer develops the pigment used in such products. The muller tests do not determine the true value of colors for this purpose. The grinding action of the muller develops the tinctorial value and hiding power of the pigment to a much greater extent than when the pigment is ground in oil on a loosely set stone mill. Comparative muller and stone grinding tests show that fifty mulls with no weight on the muller are equivalent to a loose grind on a paint mill in which the pigment is thoroughly wetted. It is recommended that this test be used in determining the true value of these pigments for paints wherein the pigment receives little or no grinding in the paint mill.

NOTE 3.—For the most exact determination of mass color and ultimate tinting strength, it is recommended that the following procedure be employed: The comparison of all samples shall be made at the same or equal consistency and this consistency shall be such that the paste can just be thrown from the spatula by a gentle whipping motion of the hand or by the tapping of the spatula blade with the index finger.

NOTE 4.—To determine the percentage strength of the unknown color in terms of the standard, varying amounts of the mulled paste of the standard color are mixed with the same amount of reduction paste to give a series of standards. The unknown is compared to determine the standard it matches. The tinting strength of the unknown sample is calculated as follows: The ratio of the amount of standard color used to give equality of tint, to the amount of unknown color used multiplied by 100 is the tinting strength of the unknown sample.

Tinting Strength, Pastes

6. When the sample is in the paste form as a color in oil or color in Japan, the tinting strength shall be determined in accordance with the procedure described in Section 4 (*b*) and continuing in Section 5 (*a*) and (*b*).

TENTATIVE METHODS OF TESTING OLEO-RESINOUS VARNISHES[1]

(SKINNING TEST, ALKALI RESISTANCE, ACID NUMBER)

A.S.T.M. Designation: D 154 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Skinning Test of Varnish in Closed Containers

Container

1. An 8-oz. wide mouth glass jar 4½ in. in height and 2 in. in diameter shall be used as the container.

Note.—Jar No. 5107 C. T. with 12S P. and O. Cap, of the Hazel-Atlas Glass Co., Wheeling, W. Va., have been found suitable.

Procedure

2. A 6-oz. sample of the varnish shall be measured into the glass jar container by means of a graduate. The cover shall be screwed on tightly, and the jar inverted momentarily. The jar shall then be placed in an upright position in the dark (placing it under a box or in a drawer is satisfactory) and the varnish shall be examined for skinning at specified time intervals.

Alkali Resistance Test

Alkali Resistance Test

3. A 1 by 6-in. test tube shall be thoroughly cleaned in benzol. The tube shall then be dipped into the sample of varnish and the mouth of the tube inverted downward immediately and the varnish allowed to dry for 48 hr. in an atmosphere free from dust, drafts, products of combustion or laboratory fumes. The temperature of the room during the drying period shall be 65 to 78 F. (19 to 25 C.). The varnish-coated tube shall then be suspended in a solution of sodium hydroxide (3 per cent) maintained at 70 ± 2 F. (21 ± 1.1 C.). The tube shall be removed after desired periods of time, such as 8, 16, 24, and 48 hr., and the varnish examined for whitening, blistering or removal. Before making the examination, the varnished tube shall be rinsed under a gentle stream of water and allowed to air dry for 30 min.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

These methods, when adopted as standard, will be added to the Standard Methods of Testing Oleo-Resinous Varnishes (A.S.T.M. Designation: D 154 - 28), 1933 Book of A.S.T.M. Standards, Part II, p. 698.

ACID NUMBER

Solutions Required

4. The following solutions will be required:

(*a*) *Alcoholic Oxalic Acid Solution* (0.1 *N*).—Dissolve 6.3 g. of c.p. oxalic acid ($H_2C_2O_4 \cdot H_2O$) in sufficient 95 per cent ethyl alcohol to make a liter.

(*b*) *Alcoholic Potassium Hydroxide* (0.1 *N*).—Dissolve approximately 6.6 g. of c.p. alcohol refined potassium hydroxide (85.86 per cent KOH) in sufficient 95 per cent ethyl alcohol to make a liter, and standardize in usual manner.

(*c*) *Neutral Solvent Mixture.*—Mix 75 per cent of ethyl alcohol (95 per cent) and 25 per cent of c.p. benzene (benzol, C_6H_6).

(*d*) *Phenolphthalein Indicator.*—Dissolve 10 g. of phenolphthalein indicator in 1 liter of ethyl alcohol (95 per cent). Use 1 ml. for titration.

Procedure

5. (*a*) A 3 to 5-g. sample of the varnish shall be weighed into a 500-ml. glass-stoppered Erlenmeyer flask, 75 ml. of the solvent mixture added and warmed slightly to aid solution. A definite accurately measured quantity (10 to 25 ml.) of the standard 0.1 *N* oxalic acid solution shall then be added. The mixture shall be refluxed on a hot plate (using a reflux condenser) for about 1 hr. or until the soaps present have been decomposed. The solution shall then be removed and titrated while hot with the standard 0.1 *N* potassium hydroxide solution using phenolphthalein indicator. As the endpoint is approached, very vigorous shaking will be required. Titrating while hot increases the speed of titration and results in a sharper endpoint. A pink coloration which persists for several minutes shall be taken as the endpoint.

(*b*) A blank containing the same quantity of the standard 0.1 *N* oxalic acid solution should be run using the same procedure as for the sample.

Calculation

6. The acid number is the weight in milligrams of potassium hydroxide required to neutralize a 1-g. sample of the varnish:

$$\text{Acid number} = \frac{(a - b)\,c}{w}$$

where a = the milliliters of potassium hydroxide required for the sample
b = the milliliters of potassium hydroxide required for the blank
c = the milligrams of potassium hydroxide per milliliter (value of standard potassium hydroxide solution)
w = the weight of the sample in grams.

TENTATIVE METHODS OF TEST
FOR
SOLUBLE NITROCELLULOSE BASE SOLUTIONS[1]

A.S.T.M. Designation: D 365 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1933; Revised, 1935.

Scope

1. These methods are intended for the testing of soluble nitrocellulose base solutions which are made by dispersing various kinds and concentrations of soluble nitrocellulose in various solvent mixtures.

2. Since the desired specifications and compositions of soluble nitrocellulose base solutions vary greatly, the limits desired for each particular type shall be mutually agreed upon by the buyer and vendor.

Sampling

3. Samples shall be taken from not less than 10 per cent of each lot in the shipment. These samples shall then be composited to represent each lot or batch.

CONSISTENCY (VISCOSITY)

Apparatus

4. The falling-ball consistency test apparatus and procedure described in Sections 11 to 13 of the Standard Specifications and Tests for Soluble Nitrocellulose (A.S.T.M. Designation: D 301) of the American Society for Testing Materials[2] shall be used to determine the consistency of those solutions having a consistency of from 3 to 500 seconds when tested in that apparatus.

5. The consistency test described in Sections 9 and 10 of the Tentative Methods of Testing Nitrocellulose Clear Lacquers and Lacquer Enamels (A.S.T.M. Designation: D 333 – 34 T) of the American Society for Testing Materials[3] shall be used to determine

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 711.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 879 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 689.

the consistency of those solutions having a consistency of less than 3 seconds when tested in the falling-ball apparatus referred to in Section 4.

6. The apparatus and method described in Sections 7 and 8 shall be used to determine the consistency of those solutions having a consistency greater than 500 seconds when tested in the falling-ball apparatus referred to in Section 4.

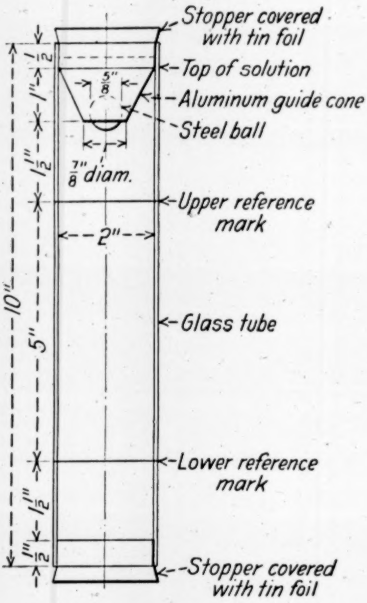
Stopper covered with tin foil
Top of solution
Aluminum guide cone
Steel ball
Upper reference mark
Glass tube
Lower reference mark
Stopper covered with tin foil
1/2"
1"
5/8"
1 1/2"
7/8" diam.
2"
10"
5"
1 1/2"
1/2"

Fig. 1.—Consistency (Viscosity) Test Apparatus.

Apparatus

7. The consistency test apparatus, shown in Fig. 1, shall consist of the following:

(*a*) *Glass Tube.*—A glass tube (preferably resistant glass),[1] 2 in. ± $\frac{1}{32}$ in. (50.8 mm. ± 1.0 mm.) in inside diameter and 10 in. in length, with marks 5 in. ± $\frac{1}{16}$ in. (177 mm. ± 1 mm.) apart, the upper one being 3 in. from the top of the tube.

(*b*) *Steel Ball.*—A $\frac{5}{8}$-in. steel ball, 0.625 in. ± 0.001 in. (15.88 mm. ± 0.02 mm.) in diameter and weighing 16.536 g. ± 0.10 g.

(*c*) *Aluminum Guide Cone.*—A guide cone of light gage aluminum (approximately 0.02 in. in thickness) as shown in Fig. 1. The orifice of the guide cone shall be $\frac{7}{8}$ in. in diameter, the conical portion 1 in. in height, the cylindrical portion $\frac{1}{2}$ in. in height, and the outside diameter shall be slightly under 2 in. so as to fit snugly into the viscosity tube.

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[1] Pyrex glass is very satisfactory for this purpose.

(*d*) *Stoppers.*—Stoppers made preferably of rubber and covered with tin foil.

Procedure

8. The consistency shall be determined as follows:

(*a*) Fill the tube in any convenient manner whereby bubbles do not form or an appreciable amount of solvent is not lost. Among other methods this can be done by immersing the lower end of the open tube in the solution and applying suction at the upper end of the tube. In this manner the tube can be filled in from 5 to 10 seconds without the introduction of air bubbles or an appreciable loss of solvent. Close the bottom of the tube with a stopper covered with tin foil. Push the aluminum guide cone slowly into the top of the tube and insert a stopper covered with tin foil into the top of the guide.

(*b*) Bring the tube and its contents to a temperature of 25 C. ± 0.1 C. by placing in a suitable bath. Allow at least 30 minutes for the solution to reach temperature equilibrium. For accurate measurements keep the tube during the determination either in a thermostat or suspended within a considerably larger cylinder of water at the specified temperature.

(*c*) Remove the upper stopper only long enough to place the ball in the center of the tube; this can be done conveniently with crucible tongs. The principal value of the guide cone is to retard the ball sufficiently at the start of its fall so that the solution will close over the ball and not leave on the top of the ball a large "trailer bubble." If the guide is not used a big trailer bubble usually accompanies the ball, retarding its fall and, if the bubble is off center on the ball, pulling the latter away from the center of the tube.

(*d*) Measure the time of fall in seconds from the instant the bottom of the ball is level with the upper reference mark on the tube until it reaches the lower mark on the tube.

NOTE.—The steel ball can be removed (in order to leave the same material in the tube for a check run) by removing the lower stopper. However, a small air bubble is usually introduced in this way. It is preferable to invert the tube, removing the guide to get the ball out. It is often necessary to put a few drops of solvent in the guide lip to loosen it from the tube on account of the solution drying at the edge of the tube. When the latter method is used for removing the ball, a larger bubble traverses the tube, than when the former method is used, but a large bubble moves sufficiently fast, even in a very viscous solution, to escape at the top in a few minutes, whereas small bubbles take hours to escape.

NON-VOLATILE MATTER

Non-Volatile Matter

9. The percentage of non-volatile matter shall be determined in accordance with the method described in Section 8 of the Tentative Methods of Testing Nitrocellulose Clear Lacquers and Lacquer Enamels (D 333 - 34 T) of the American Society for Testing Materials.[1]

APPEARANCE OF SOLUTION

Appearance

10. The appearance of the soluble nitrocellulose base solution shall be compared with a standard mutually agreed upon by the buyer and vendor (both standard and sample solutions shall be thoroughly agitated before making observations) in similar bottles for turbidity, hair, grain, and insoluble matter.

DEPTH OF COLOR

Apparatus

11. The apparatus used for the preparation of the color standards and for the depth of color determinations shall consist of the following:

(*a*) *Light*.—Source of transmitted light.[2]
(*b*) *Bottles*.—Three dozen 2-oz. screw-cap, square, glass bottles.
(*c*) *Flasks*.—Several 1-liter volumetric flasks.
(*d*) *Burettes*.—Two 50-ml. burettes.
(*e*) *Balance*.—An analytical balance.
(*f*) *Colorimter*.—Dubosq colorimeter.[2]
(*g*) *Color Glass*.—A piece about 25 mm. square and 10 mm. thick of Corning glass, Signal Yellow No. 330.

Chemicals

12. The following chemicals will be required:

(*a*) Chemically pure potassium platinic chloride (K_2PtCl_6).
(*b*) Chemically pure cobalt chloride ($CoCl_2 . 6H_2O$).
(*c*) Concentrated hydrochloric acid.
(*d*) Caramel (sugar coloring).
(*e*) Phenol.

Preparation of Color Standards

13. *Platinum-Cobalt Color Standards*.—The platinum-cobalt color standards shall be prepared as follows:

(*a*) Weigh out on an analytical balance exactly 1.246 g. of c.p.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 879 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 689.

[2] Not absolutely necessary, but will increase accuracy and be more convenient.

potassium platinic chloride (K_2PtCl_6) and 1.000 g. of c.p. crystallized cobalt chloride ($CoCl_2.6H_2O$). Dissolve in distilled water, add 100 ml. of concentrated HCl and dilute to 1000 ml. with distilled water. This solution is color standard No. 10.[1]

(*b*) Prepare color standards Nos. 1 to 10, inclusive, by accurately measuring from burettes directly into the square 2-oz. bottles the following quantities of the No. 10 color standard and distilled water:

COLOR STANDARDS	QUANTITY OF No. 10 COLOR STANDARD, ML.	QUANTITY OF DISTILLED WATER, ML.
No. 1	5	45
No. 2	10	40
No. 3	15	35
No. 4	20	30
No. 5	25	25
No. 6	30	20
No. 7	35	15
No. 8	40	10
No. 9	45	5
No. 10	50	0

(*c*) After preparation of the color standards the bottles shall be sealed with corks and paraffin before putting on the screw caps. The platinum-cobalt standards are permanent for approximately six months. The color standards from No. 12 to No. 500, inclusive, are made from a caramel solution, but the color is based on the platinum-cobalt color standard.

14. *Caramel Standards.*—The caramel standards shall be prepared as follows:

(*a*) Dilute caramel (sugar coloring) in the ratio of about 1 ml. of caramel to 100 ml. of distilled water in a glass vessel. Add 0.5 per cent phenol and agitate thoroughly. Adjust the concentration of this solution so that when it is diluted in the ratio of 1 ml. of solution to 49 ml. of distilled water, to which has been added 0.5 per cent phenol, the solution will match color No. 10 of the platinum-cobalt color standard. This caramel solution before dilution is color No. 500 (Note).

NOTE.—It is more convenient to check the caramel color standard No. 500 against a colored glass which has been previously standardized against the platinum-cobalt color standard; a piece of glass about 25 mm. square by 10 mm. thick of Signal Yellow No. 330 manufactured by the Corning Glass Works may be standardized and used as a check on the caramel solution. This must be done by use of a colorimeter.

(*b*) Prepare color standards No. 12 to No. 500, inclusive, by accurately measuring from burettes directly into the square 2-oz.

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[1] This solution has an assigned value of 500 on the Hazen color scale, see *American Chemical Journal*, Vol. XIV, p. 300.

bottles the quantities shown in Table I of color No. 500 caramel standard and distilled water to which has been added 0.5 per cent phenol.

(*c*) After preparation of the color standards, the bottles shall be sealed with corks and paraffin before putting on the screw caps. All of the caramel color standards are permanent for approximately one month but should be checked semimonthly.

Procedure

15. *Comparison of Material to be Tested with Color Standards.*—A square 2-oz. glass bottle shall be filled with the material to be tested and this shall be matched against one of the color standards using either direct daylight or indirect artificial transmitted light, the latter being preferred. The number of the color standard matched is the depth of color of the material.

TABLE I.

COLOR STANDARDS	QUANTITY OF CARAMEL SOLUTION, ML.	QUANTITY OF DISTILLED WATER PLUS PHENOL, ML.
No. 12	1.2	48.8
No. 15	1.5	48.5
No. 20	2.0	48.0
No. 25	2.5	47.5
No. 30	3.0	47.0
No. 35	3.5	46.5
No. 40	4.0	46.0
No. 45	4.5	45.5
No. 50	5.0	45.0
No. 60	6.0	44.0
No. 70	7.0	43.0
No. 75	7.5	42.5
No. 80	8.0	42.0
No. 90	9.0	41.0
No. 100	10.0	40.0
No. 125	12.5	37.5
No. 150	15.0	35.0
No. 175	17.5	32.5
No. 200	20.0	30.0
No. 250	25.0	25.0
No. 300	30.0	20.0
No. 350	35.0	15.0
No. 400	40.0	10.0
No. 450	45.0	5.0
No. 500	50.0	0.0

TENTATIVE SPECIFICATIONS

FOR

WOOD TO BE USED AS PANELS IN WEATHER TESTS OF PAINTS AND VARNISHES[1]

A.S.T.M. Designation: D 358 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1935.[2]

Purpose and Scope

1. These specifications designate woods for weathering tests on exterior oil paints and other materials of similar purpose. Such tests may include either outdoor exposure tests or accelerated laboratory tests. According to experience, the wood used as a test surface has a marked bearing upon weathering results, especially in accelerated laboratory tests or 45 deg. outdoor exposures. It is the purpose of these specifications to maintain more uniformity of the influence of the wood, particularly in cooperative work among different laboratories. The cedar and white pine, as specified, are desirable for determining general durability factors. Cedar, as specified, is affected less by the exposure conditions and is preferred for rapid accelerated tests (laboratory and 45 deg. outdoor exposures) to avoid the masking of the true failure characteristics of the coating by unusual changes in the wood surface. From this standpoint white pine, as specified, represents an intermediate wood. Southern yellow pine, as specified, emphasizes the influence of wood on adhesion and durability of the coating.

WESTERN RED CEDAR

Species

2. The material for test panels shall be western red cedar (*Thuja plicata*).

Weight per Cubic Foot

3. The wood shall weigh 22 to 23 lb. per cu. ft. The weight shall be determined after at least one week's storage in a protected, dry, warm atmosphere (approximately 70 F.).

Character of Wood

4. The material shall be close grained, as nearly edge grain as possible and in no section to vary more than 45 deg. from edge grain.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

WHITE PINE

Species

5. The white pine wood shall be restricted to northern white pine (*Pinus strobus*) and Idaho white pine (*Pinus monticola*).

Weight per Cubic Foot

6. The wood shall weigh 24 to 26 lb. per cu. ft. when wood is in equilibrium with air at 60 to 65 per cent relative humidity and 69 to 71 F. (21.5 to 21.6 C.) (wood at approximately 12 per cent moisture content).

Character of Wood

7. The wood shall be free from knots, pitch pockets, pitch streaks and other defects. The number of annual growth rings per inch along the radius of the log from which obtained shall not be less than 18. The test surface shall be smoothly planed and reasonably free from planer marks and chipped or torn grain.

8. The wood shall be selected as edge grain or flat grain as desired. Specimens in which the annual growth rings intersect the planed test surface at an angle of 45 deg. or more shall be considered edge grain, and similarly specimens in which the intersection is at an angle of 15 deg. or less shall be considered as flat grain. The test surface of flat grain wood shall be on the bark side.

SOUTHERN YELLOW PINE

Species

9. The material for test panels shall be southern yellow pine, suitable for siding purposes. It is not to be limited to a single species, but shall conform to the requirements hereinafter stated.

Weight per Cubic Foot

10. The wood shall weigh 32 to 38 lb. per cu. ft. when wood is in equilibrium with air at 60 to 65 per cent relative humidity and 69 to 71 F. (wood at approximately 12 per cent moisture content).

Character of Wood

11. The wood shall be free from knots, pitch pockets, pitch streaks and other defects. The number of annual growth rings per inch along the radius of the log from which obtained shall not be less than 7 nor more than 9. The test surface shall be on the bark side and shall be smoothly planed and reasonably free from planer marks and chipped or torn grain.

12. The wood shall be selected as flat grain; specimens in which the annual growth rings intersect the planed test surface at an angle of 15 deg. or less shall be considered as flat grain.

TENTATIVE METHOD OF TEST

FOR

FLASH POINT BY MEANS OF THE TAG CLOSED TESTER[1]

A.S.T.M. Designation: D 56 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. The Tag closed tester shall be used for determining the flash point of all mobile liquids (Note) flashing below 175 F., with the exception of products classed as fuel oil which are preferably tested with the Pensky-Martens Closed Tester as described in the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93) of the American Society for Testing Materials.[2]

NOTE.—Provision is made in Sections 12 and 13 of this method for determining the flash point of lacquer solvents or diluents of low flash points.

APPARATUS

Tag Closed Tester

2. The Tag closed tester, a diagram of which appears in Fig. 1, shall conform to the following dimensional requirements within the permissible variations shown:

DIMENSIONS	INCHES			CENTIMETERS		
	MIN.	NORMAL	MAX.	MIN.	NORMAL	MAX.
Depth of water surface below top of cup..	$1\frac{5}{64}$	$1\frac{3}{32}$	$1\frac{7}{64}$	2.74	2.78	2.82
Depth of oil surface below top of cup.....	$1\frac{9}{64}$	$1\frac{5}{32}$	$1\frac{11}{64}$	2.90	2.94	2.98
Depth of top of bulb of oil thermometer when in place below top of cup.......	$1\frac{9}{32}$	$1\frac{5}{16}$	$1\frac{11}{32}$	3.25	3.33	3.41
Inside diameter of oil cup at top.........	$2\frac{12}{100}$	$2\frac{1}{8}$	$2\frac{13}{100}$	5.39	5.40	5.41
Diameter of bead on top of cover.........	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	0.36	0.40	0.44
Weight of oil cup..						67 to 69 g.

The plane of underside of cover shall be between the top and bottom of the burner tip when the tip is fully depressed.

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[1] Under the standardization procedure of the Society, this method is under the joint jurisdiction of A.S.T.M. Committee D-1 on Preservative Coatings for Structural Materials and Committee D-2 on Petroleum Products and Lubricants.

This tentative method is in effect a tentative revision of, and is intended to supersede when adopted as standard, the present Standard Method of Test for Flash Point of Volatile Flammable Liquids (A.S.T.M. Designation: D 56 – 21), see 1933 Book of A.S.T.M. Standards, Part II, p. 663.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 805.

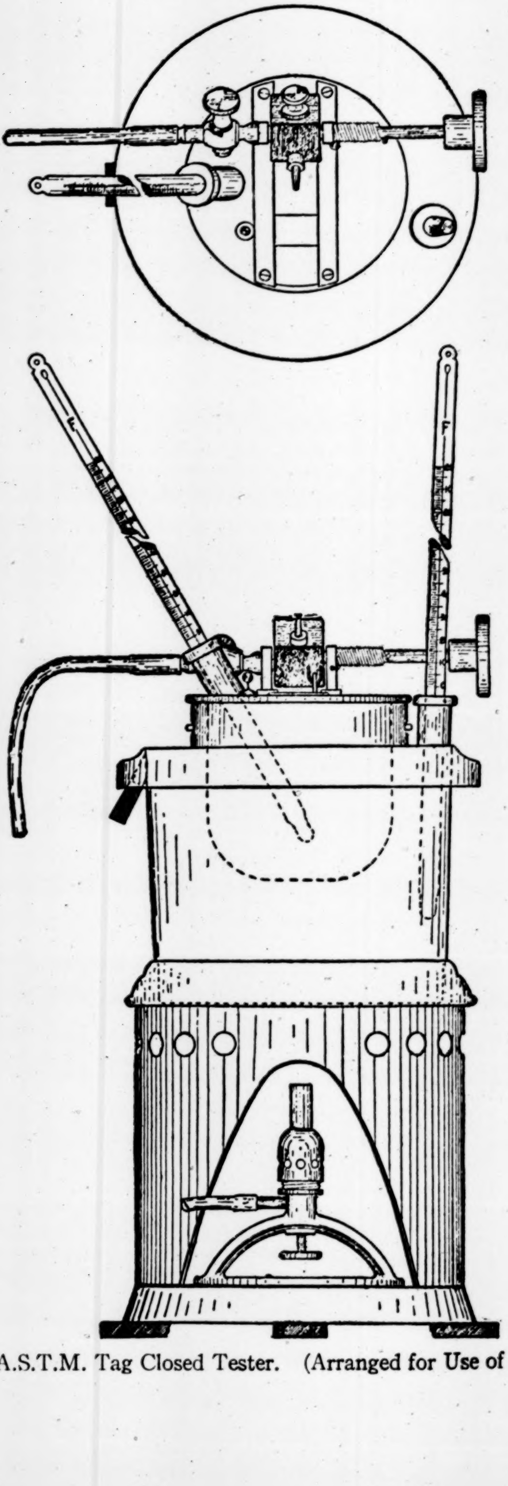

FIG. 1.—A.S.T.M. Tag Closed Tester. (Arranged for Use of Gas.)

Thermometer

3. Two thermometers are required, one for measuring the temperature of the sample under test, the other for measuring the temperature of the bath. Each of these thermometers shall conform to the following requirements. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −7 to +110 C. or +20 to +230 F., respectively:

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: −7 to +110 C. in 0.5 C. or +20 to +230 F. in 1 F.

Total Length: 273 to 277 mm. (10.75 to 10.92 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, 9 to 13 mm. (0.35 to 0.51 in.).
Diameter, not greater than stem.

Distance to −7 C. or +20 F. Line from Bottom of Bulb: 75 to 90 mm. (2.93 to 3.54 in.).

Distance to 110 C. or 230 F. Line from Top of Thermometer: 25 to 40 mm. (0.98 to 1.57 in.).

Expansion Chamber: To permit heating the thermometer at least 50 C. (90 F.) above highest temperature on scale.

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures, and letters clear cut and distinct. The whole degree Centigrade lines or the first and each succeeding 5 F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 5 C. or 10 F.

Immersion: 57 mm. or 2¼ in. The words "57-mm. immersion" on Centigrade or "2¼-in. immersion" on Fahrenheit thermometers and a line around the stem 57.0 mm. or 2.25 in. above the bottom of the bulb shall be etched on the thermometer.

Special Marking:[1] "A.S.T.M. P.M. and Tag.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.5 C. or 1 F., respectively.

Standardization: The thermometer shall be standardized at the ice point and at intervals of approximately 30 C. or 50 F. for 57-mm. or 2¼-in. immersion and for the following temperatures of the emergent mercury column:

Thermometer Reading		Average Temperature of Emergent Mercury Column	
20 C.	70 F.	20 C.	70 F.
40 C.	100 F.	31 C.	86 F.
70 C.	150 F.	40 C.	104 F.
100 C.	212 F.	48 C.	118 F.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. P.M. and Tag., −7 to +110 C." or "A.S.T.M. P.M. and Tag., +20 to +230 F." according to the type of thermometer.

Note.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.
The diameter is that measured with a ring gage.
The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.
The top of the thermometer is the top of the finished instrument.

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[1] This thermometer is identical with the low range instrument specified for use with the A.S.T.M. Pensky-Martens Closed Tester and described in the Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93) of the American Society for Testing Materials, see 1933 Book of A.S.T.M. Standards, Part II, p. 805.

PROCEDURE

Procedure

4. (*a*) The test shall be performed in a room or compartment darkened sufficiently to permit ready detection of the flash.

(*b*) Care shall be taken to have the tester level and steady. It shall be surrounded on three sides by an enclosure for protection from drafts. (A shield 18 in. square and 24 in. in height, open in front, is suggested. Tests made in a laboratory hood or near ventilators are not to be relied upon.)

(*c*) Gas may be used for the test flame and for heating the water bath. If gas is not available for the test flame, a wick of cotton cord may be inserted in the burner tip, a small quantity of cotton waste placed in the oil chamber to which the burner tip is attached and the chamber filled with signal, sperm, or lard oil. An alcohol lamp may be used for heating the water bath as a substitute for gas.

5. The water bath thermometer shall be placed in the collar provided for it and the bath filled with water until it overflows. The temperature of the water in the bath shall be such that when testing is started it will be at least 20 F. (11 C) below the probable flash point of the oil to be tested.

6. The oil cup shall be placed in its proper position in the water bath and 50 ml. of the oil to be tested shall be measured into it, using an accurate graduate or other measuring device for the purpose. The temperature of the oil shall be at least 20 F. (11 C.) below its probable flash point when the test is started. Air bubbles on the surface of the oil shall be destroyed, and the cover with the flash point thermometer in place shall then be properly attached to the bath collar. The test flame shall be lighted, the flame being adjusted to the size of the small white bead on the cover.

7. The gas burner or alcohol lamp shall be centrally placed in the base of the tester and lighted. The flame shall be so adjusted that the temperature of the oil in the cup rises at the rate of 1.8 F. (1 C.) per min. as closely as possible, but in any case not faster than 2 F. (1.1 C.) nor slower than 1.6 F. (0.9 C.) per min.

8. (*a*) The barometric pressure shall be recorded. If a barometer is not available, the figure may be obtained from the nearest Weather Bureau Station and an appropriate correction made for difference in altitude between such station and the laboratory.

(*b*) The initial temperature of the oil shall be recorded.

(*c*) When the temperature of the oil is 9 F. (5 C.) below its probable flash point, the knob on the cover shall be turned in such a manner as to introduce the test flame into the vapor space of the cup, and *immediately* turned back again. The time consumed in turning the knob down and back shall be about one full second, or the time required to pronounce distinctly the words "thousand and one."

(*d*) The time at which the first introduction of the test flame is made and the temperature of the oil shall be recorded.

(*e*) The application of the test flame shall be repeated after each 1 F. (0.5 C.) rise in temperature of the oil until a distinct flash in the interior of the cup is observed. The true flash must not be confused with the bluish halo which sometimes surrounds the test flame during applications immediately preceding the actual flash.

(*f*) The time and the temperature of the oil when the flash point is reached shall be recorded.

Repeat Tests

9. (*a*) If the rise in temperature of the oil from the time of making the first introduction of the test flame to the time at which the flash point is observed was more rapid than 2 F. (1.1 C.), or slower than 1.6 F. (0.9 C.) per min., the test shall be repeated, adjusting the gas burner or alcohol lamp to the proper rate of heating.

(*b*) It is not necessary to turn off the test flame with the small regulating valve on the cover; it may be left adjusted to the proper size of flame.

(*c*) After completing the preliminary test to determine the approximate flash point, the burner or lamp shall be removed, the oil cover lifted and the thermometer bulb carefully wiped off. The oil cup shall be removed, emptied, and carefully wiped until dry.

(*d*) The temperature of the bath shall be lowered by the addition of cold water until it is 15 F. (8 C.) below the flash point of the oil as shown by the preliminary test.

(*e*) The oil cup shall be replaced and a fresh 50-ml. sample measured into it. The test procedure, as described in Sections 4 to 6, inclusive, shall then be repeated, introducing the test flame for the first time, however, when the oil temperature is 10 F. (5.5 C.) below the flash point obtained in the preliminary test.

(*f*) Oil which has once been subjected to the flash test shall be discarded.

(*g*) If test is to be repeated, a fresh sample shall be used.

Average Value of Flash Point

10. If two or more determinations agree within 1 F. (0.5 C.), the average of these results, corrected for barometric pressure, shall be considered the flash point. If two determinations do not check within 1 F. (0.5 C.), a third determination shall be made and, if the maximum variation of the three tests is not greater than 2 F. (1 C.), their average, after correcting for barometric pressure, shall be considered the flash point.

Correction for Barometric Pressure

11. Correction for barometric pressure shall be made only in cases of dispute or when the barometer reading varies more than ½ in. (13 mm.) from the standard pressure of 29.92 in. (760 mm.). When the barometer reading is below this standard pressure, add to the thermometer reading 1.6 F. (0.9 C.) for each 1 in. (25 mm.) of barometer difference to obtain the true flash point. When the barometer reading is above the standard pressure, deduct 1.6 F. (0.9 C.) for each 1 in. (25 mm.) of barometer difference to obtain the true flash point.

Determination of Flash Point of Lacquer Solvents or Diluents of Low Flash Point

Apparatus

12. The apparatus shall consist of the following:

(*a*) *Flash Point Tester.*—As described in Section 2.

(*b*) *Thermometer.*—For determining flash points below 40 F. (4.4 C.), thermometers graduated either in Fahrenheit or Centigrade degrees, having ranges of 0 F. to 210 F., or −20 C. to +100 C., shall be used. Otherwise the thermometers shall conform to the requirements prescribed in Section 3. These thermometers may be used optionally for the determination of flash points above 40 F.

Procedure

13. The procedure shall be the same as described in Sections 4 to 11 except that in determining flash points below 40 F. (4.4 C.) the bath shall be filled with brine instead of water.

TENTATIVE METHOD OF TEST

FOR

VAPOR PRESSURE OF MOTOR AND AVIATION GASOLINE (REID METHOD)[1]

A.S.T.M. Designation: D 417 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method is intended for the determination of the vapor pressure of motor and aviation gasoline. It may be used on other gasolines (Note).

NOTE.—Present indications are that reliable results can be obtained by this method on gasolines of 28-lb. vapor pressure, or less. Probable exceptions are gasolines of somewhat lower vapor pressure containing appreciable quantities of dissolved gases.

APPARATUS

Vapor-Pressure Bomb

2. The vapor-pressure bomb consisting of two sections or chambers, an upper section, or air chamber, and a lower section, or gasoline chamber, shall conform to the following requirements:

(*a*) *Air Chamber.*—The upper section, or air chamber, shown in Fig. 1, shall be a cylindrical vessel 2 to $2\frac{1}{8}$ in. in diameter and 10 in. $\pm\frac{1}{8}$ in. in length, inside dimensions. In one end of the air chamber a $\frac{1}{4}$-in. standard pipe thread shall be tapped, to receive the gage coupling. Other means of connecting the air chamber with the pressure gage may be employed, provided the requirements of Paragraphs (*c*) and (*d*) are fulfilled. In the other end of the air chamber an opening approximately $\frac{1}{2}$ in. in diameter shall be provided for purposes of coupling with the gasoline chamber. The nature of this opening will depend upon the method of coupling employed. The air chamber must drain completey from either end when held in a vertical position and for this reason the ends may be slightly convex.

(*b*) *Gasoline Chamber.*—The lower section, or gasoline chamber, shown in Fig. 1, shall be a cylindrical vessel of the same inside diameter as the air chamber and $2\frac{1}{2}$ in. $\pm\frac{1}{16}$in. in inside length. In one end of the gasoline chamber an opening approximately ½ in. in diameter shall be provided for purposes of coupling with the air chamber. The nature of this opening will depend upon the method of coupling employed. The other end of the gasoline chamber shall be completely closed. The gasoline chamber must drain completely when inverted and for this reason the top may be slightly convex.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

(*c*) *Method of Coupling Air and Gasoline Chambers.*—Any method of coupling the air and gasoline chambers may be employed, for example, a simple thread, a union, or a clamp. The sole provision in this respect is that the assembly shall be free from leaks under the conditions of test. Responsibility for freedom from leaks rests with the user.

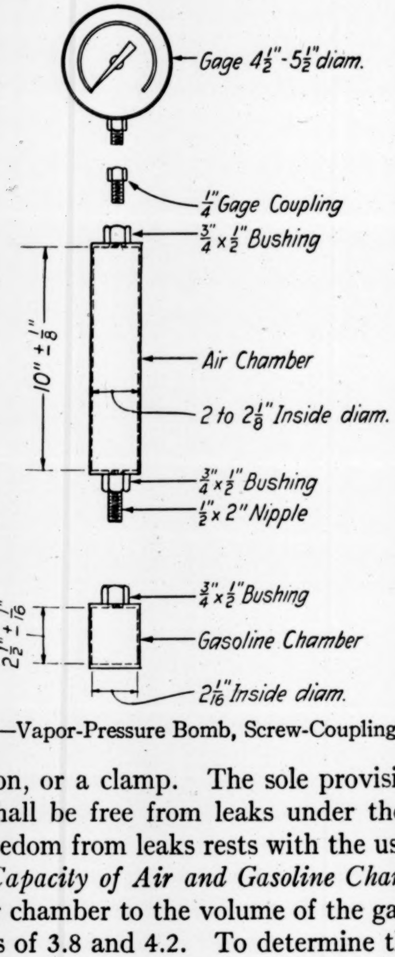


FIG. 1.—Vapor-Pressure Bomb, Screw-Coupling Type.

(*d*) *Volumetric Capacity of Air and Gasoline Chambers.*—The ratio of the volume of the air chamber to the volume of the gasoline chamber shall be between the limits of 3.8 and 4.2. To determine the volume of the air chamber, insert a ¼-in. plug in the gage coupling, invert the chamber, fill with water up to and including the portion of the coupling device attached permanently to the air chamber and then carefully measure the volume of water. To determine the volume of the gasoline chamber, fill with water up to and including the portion of the coupling device attached permanently to the gasoline chamber, and then carefully measure the volume of water.

(*e*) *Checking for Freedom from Leaks.*—Before placing new apparatus in service and as often as necessary thereafter, the assembled bomb shall be checked for freedom from leaks by filling with air to 100-lb. gage pressure and completely immersing in a water bath. Only apparatus which will stand this test without leaking shall be used.

Pressure Gage

3. (*a*) The pressure gage shall be a Bourdon-type spring gage of test-gage quality $4\frac{1}{2}$ to $5\frac{1}{2}$ in. in diameter. The range of the pressure gage used shall be governed by the vapor pressure of the sample being tested as follows:

Vapor Pressure, lb. per sq. in. at 100 F.	Gage to be Used[a] Scale Range	Numbered Intervals	Intermediate Graduations
12 and under	0 to 15 lb.	3 lb.	0.1 lb.
10 to 30	0 to 45 lb.	5 lb.	0.2 lb.

[a] A gage of 0 to 30-lb. range, 5-lb. numbered intervals and 0.2-lb. intermediate graduations may be used for products of from 10 to 22-lb. vapor pressure.

(*b*) Only accurate gages shall be continued in use.

Cooling Bath

4. A cooling bath shall be provided of such dimensions that the sample containers and gasoline chambers may be completely immersed. Means for maintaining the bath at a temperature of 32 to 40 F. shall be provided.

Water Bath

5. The water bath shall be of such dimensions that the vapor-pressure bomb may be immersed to the bottom of the pressure gage. Means for maintaining the bath at a constant temperature of 100 F. ±0.2 F. shall be provided.

Water Bath Thermometer

6. The thermometer for measuring the water-bath temperature shall conform to the following requirements:

Type: Etched stem, glass.
Liquid: Mercury
Range and Subdivisions: Range 94 to 108 F., subdivisions in 0.2 F.
Total Length: 252 to 256 mm. (9.92 to 10.08 in.).
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.24 to 0.28 in.).
Bulb: Corning normal or equally suitable thermometric glass.
  Length, 25 to 35 mm. (1.0 to 1.4 in.).
  Diameter, not less than 5 mm. (0.20 in.) and not greater than that of stem.
Distance to Lowest Specified Graduation from Bottom of Bulb: 135 to 150 mm. (5.3 to 5.9 in.).
Distance to Highest Specified Graduation from Top of Thermometer: 20 to 35 mm. (0.8 to 1.4 in.).

CONTRACTION CHAMBER: To be of long narrow type, top to be not more than 60 mm. (2.36 in.) above bottom of bulb, mercury to stand in contraction chamber at 32 F.
EXPANSION CHAMBER: To permit heating the thermometer 90 F. above highest temperature on scale, and in all cases to permit heating to 212 F.
FILLING ABOVE MERCURY: Nitrogen gas.
TOP FINISH: Glass ring.
GRADUATION: All lines, figures and letters clear cut and distinct. The first and each succeeding 1 F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 F.
IMMERSION: Total.
SPECIAL MARKING: The A.S.T.M. Reid-vapor-pressure test point of 100 F. to be numbered in red, other graduations and figures in black. A serial number and the manufacturer's name or trade mark shall be etched on the stem.
SCALE ERROR: The error at any point of the scale shall not exceed 0.2 F.
STANDARDIZATION: The thermometers are to be standardized for the condition of total immersion. Correction for emergent stem shall not be applied.
CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Reid-Vapor-Pressure Thermometer."

Air Chamber Thermometer

7. The thermometer for measuring the temperature of the air chamber shall conform to the following requirements:

TYPE: Etched stem, glass.
LIQUID: Mercury.
TOTAL LENGTH: 254 to 305 mm. (10.0 to 12.0 in.).
RANGE AND SUBDIVISIONS: Range—30 to + 120 F., subdivisions in 1 F.
STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.24 to 0.28 in.).
BULB: Corning normal or equally suitable thermometric glass.
Length, not over 25 mm. (1.0 in.).
IMMERSION: Total.
SCALE ERROR: The error at any point of the scale shall not exceed 0.5 per cent of the scale range.

Chilled Sampling Apparatus

8. The chilled sampling apparatus shall consist of a bath of sufficient size to accommodate both the sample container and a cooling coil formed of $\frac{1}{4}$-in. outside diameter, No. 20 gage copper tubing. One end of the cooling coil shall be provided with connections suitable for attaching to the tank sampling connection and the other end shall be provided with a $\frac{1}{8}$-in. needle valve of good quality. For introducing the sample into the container this valve shall have at its open end a removable tube of $\frac{1}{4}$-in. outside diameter copper tubing of sufficient length to reach the bottom of the sample container. A bath of suitable design is shown in Fig. 2.

Sample Containers and Transfer Connections

9. The two types of containers for obtaining samples of gasoline for vapor-pressure tests shall conform to the following general requirements: The containers shall be at least one quart in size and of ample strength to withstand the pressures to which they may be subjected. The construction shall be such that the containers may be easily and securely sealed. Container openings in all cases shall be of a type which will permit the replacement of the cap, stopper, or plug with the connections provided for transferring samples to the gasoline chamber.

(*a*) *Open-Type Containers.*—Containers classed as open-type containers shall be provided with a single opening. Such containers shall be of a type which will readily permit sampling by immersion.

The sample transfer connection for the open-type container shall consist of two tubes assembled in a replacement cap or stopper. One of these tubes, the air tube, shall extend to the bottom of the sample container. The second tube, the liquid-delivery tube, shall be flush with the inside face of the cap or stopper and shall extend beyond the cap or stopper for a sufficient length to reach to the bottom of the gasoline chamber in the sample-transfer operation.

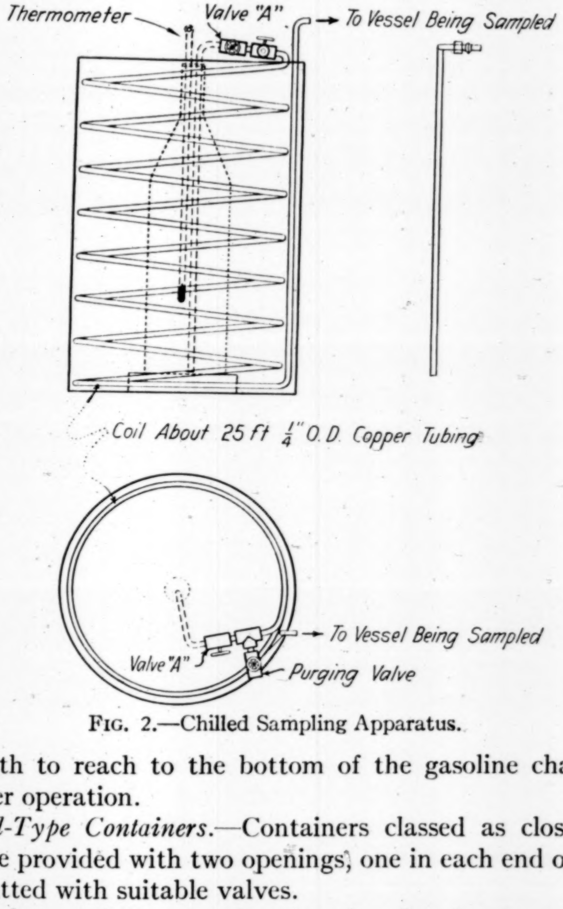


FIG. 2.—Chilled Sampling Apparatus.

(*b*) *Closed-Type Containers.*—Containers classed as closed-type containers shall be provided with two openings, one in each end or the equivalent thereof, fitted with suitable valves.

The sample-transfer connection for the closed-type container shall consist of a single tube with fittings suitable for connection to one of the openings of the sample container, the tube being of sufficient length to reach to the bottom of the gasoline chamber in the sample-transfer operation.

SAMPLING

10. The following general remarks apply to all sampling for Reid-vapor-pressure determinations. The extreme sensitivity of vapor-pressure measurements to losses through evaporation and to slight changes in composition is such as to require the utmost precautions and the most meticulous care both in the obtaining and in the handling of samples to insure their being representative. Official samples shall be taken by, or under the immediate direction of, a person of judgment, skill and previous experience in sampling for vapor-pressure measurements.

Sampling Open Tank Cars and Small Open Tanks

11. Open-type sample containers shall be used for sampling open tank cars and small open tanks. The empty sample container shall first be immersed in the car or tank of liquid to be tested and allowed to fill while being lowered and raised through the liquid. The first filling is for the purpose of washing the container thoroughly. The container shall be emptied and then refilled. On this second filling the sample container shall be lowered and raised at such a rate that it will be nearly but not quite full when withdrawn. Enough of the contents shall be poured off immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity The sample container shall be promptly sealed.

Sampling Other Vessels

12. For obtaining samples from other sizes or types of vessels than those described in Section 11, the following general remarks apply: The methods of sampling, points of sampling, and number of samples shall be as agreed upon by the contracting parties but in all cases the procedure followed shall result in obtaining representative samples. Due to the sensitivity of this method of test to handling losses, compositing of samples to arrive at an average vapor pressure for the contents of large vessels shall not be permitted.

(*a*) *Sampling into Open Sample Containers.*—Open-type sample containers shall be used for obtaining samples from large open tanks and may be used for obtaining samples from closed or pressure tanks of all products included within the scope of this method. In both cases the containers shall be rinsed with the product to be sampled immediately prior to obtaining the sample. The container shall then be refilled. If necessary, enough of the contents shall be poured off immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity. The sample container shall be promptly sealed. The sampling shall be conducted under such conditions that the sample in the sample container is at a temperature of 32 to 40 F. for the duration of sampling. If this requires the use of the chilled sampling equipment (Section 8 and Fig. 2), sufficient volume shall be wasted through the cooling coil to insure complete purging. During the sampling operation, the outlet valve (*A*, Fig. 2) shall be throttled so as to maintain a pressure in the chilling coil equivalent approximately to that in the vessel being sampled.

(*b*) *Sampling into Closed-Type Sample Containers.*—Closed-type sample containers may be used for obtaining samples from closed vessels. The inlet valve of the container shall be connected to the sampling line from the pressure vessel. During the sampling operation, the outlet valve of the container shall be throttled so as to maintain a pressure in the container equivalent approximately to that in the vessel being sampled. The sample shall be drawn by allowing the product to flow through the sampling system until a volume equal to at least twice that of the sample container has been passed. Valves shall then be closed and the container disconnected. Enough of the contents shall be withdrawn immediately so that the portion remaining shall fill the sample container to not less than 70 per cent and not more than 80 per cent of its capacity. Should the vapor pressure of the product be insufficient to force liquid from the container, it shall be permissible to open both valves to facilitate the withdrawal of the amount specified. The sample container shall be promptly sealed.

Care of Samples

13. Samples shall be put in a cool place as soon as possible after they have been obtained and held there until all tests have been completed. Samples in leaky containers shall not be considered for tests but shall be discarded and new samples obtained.

PROCEDURE

Preparation of Apparatus

14. If tests have been previously conducted in the apparatus to be used, the procedure prescribed in the following Paragraphs (*a*) to (*c*) shall be followed to prepare the apparatus for the next test. These operations are most conveniently done at the conclusion of each test.

(*a*) The air chamber, gasoline chamber and pressure gage shall be disconnected.

(*b*) The pressure gage shall be purged of residual gasoline by directing a small jet of air into its Bourdon tube for at least 5 min.

(*c*) The air chamber shall be thoroughly purged of liquid gasoline and gasoline vapors by filling the air chamber with warm water (above 90 F.) and allowing it to drain, repeating the operation at least five times (Note).

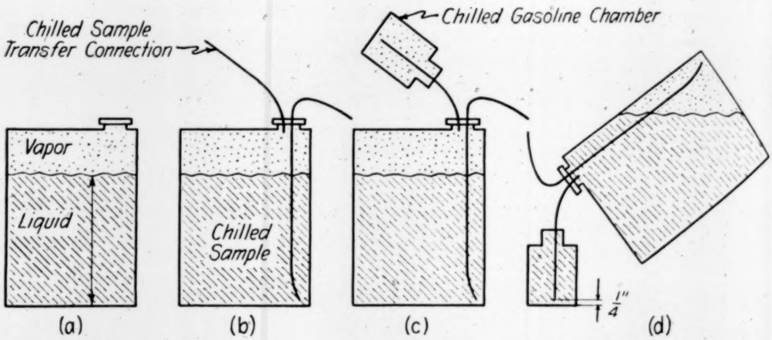
NOTE.—If this purging is done in a bath be sure to avoid small and unnoticeable films of floating gasoline by keeping the bottom and top openings of the air chamber closed as they pass through the surface of the water.

Saturation of Samples in Sample Containers

15. Prior to the Reid-vapor-pressure determinations, the sample container shall be immersed in the cooling bath (Section 4) held at a temperature of 32 to 40 F. for a sufficient time to allow the liquid to reach the bath temperature. The container shall then be unsealed for 5 sec., resealed, shaken vigorously, and then returned to the bath.

Sample Transfer; "Initial Air Temperature"; Assembly

16. (*a*) The air chamber shall be rinsed (see Note, Section 14 (*c*)) with clean water (temperature optional).



(a) Sample Container Prior to Transfer of Sample

(b) Sealing Closure Replaced by Sample Transfer Connection

(c) Gasoline Chamber Placed Over Liquid Delivery Tube

(d) Position of System for Sample Transfer

FIG. 3.—Simplified Sketches Outlining Method of Transferring Sample to Gasoline Chamber from Open-Type Containers.

(*b*) The pressure gage shall then be attached to the air chamber.

(*c*) The air thermometer shall next be inserted in the air chamber for three-fourths of its length. The bulb shall not be permitted to rest on the wall of the air chamber.

(*d*) The gasoline chamber and the sample-transfer connection shall be chilled in the cooling bath.

(*e*) With everything in readiness the chilled sample container shall be removed from the bath, the cap, stopper or plug shall be removed and the transfer connection immediately attached to the sample container. (See Fig. 3.)

(*f*) The chilled gasoline chamber shall then be placed over the sample-delivery tube of the transfer connection. The entire system shall then be rapidly inverted so that the gasoline chamber is finally in an upright position with the delivery tube extending to within $\frac{1}{4}$ in. of the bottom of the gasoline chamber. In the case of closed type containers the valves (or valve) shall not be opened until the system has reached its final position (Note). The gasoline chamber shall be filled to overflowing.

NOTE.—The valve on the sample-delivery tube should be opened first. If liquid does not flow, it will be necessary to open the second valve.

(*g*) The temperature of the air and water vapor in the air chamber shall be read. Since it is absolutely necessary that this temperature shall be the actual temperature of the air and water vapor in the air chamber at the time of final assembly (Paragraph (*h*)), the air thermometer shall have been in the air chamber (Paragraph (*c*)) at least 5 min. before the temperature is read. This temperature shall be recorded as the "initial air temperature."

(*h*) The air chamber with pressure gage attached (Paragraph (*b*)) shall be immediately attached to the gasoline chamber (Note).

NOTE.—If a threaded coupling is employed a little water-soluble grease or other low-vapor-pressure lute on the threads will materially assist in making a tight connection.

(*i*) The time interval between the operations prescribed in Paragraphs (*f*), (*g*) and (*h*) shall be as short as possible.

Vapor-Pressure Determination

17. (*a*) The assembled vapor-pressure bomb shall then be turned upside down and shaken vigorously in this position. This operation shall be repeated several times.

(*b*) The bomb shall then be righted and immersed up to the bottom of the pressure gage in the water bath (Section 5).

(*c*) The water bath shall be maintained throughout the vapor-pressure determination at a constant temperature of 100 F. ±0.2 F. as determined by the bath thermometer (Section 6) well immersed in the bath.

(*d*) While the bomb is immersed in the bath, it shall be closely observed for leaks. Liquid leaks are much more difficult to detect than vapor leaks and since the much used coupling device is normally in the liquid section of the apparatus it shall be given particular attention. When, at any time in the course of the test, a leak is detected the test shall be discarded.

(*e*) After 5 min. the bomb shall be withdrawn from the bath, inverted, shaken vigorously and replaced in the bath. Thereafter, at intervals of not less than 2 min., the bomb shall be withdrawn from the bath, inverted, shaken vigorously and replaced in the bath. This vigorous shaking shall be performed quickly to avoid cooling the bomb and its contents.

(*f*) Prior to each removal of the bomb from the bath, the gage reading shall be observed. The gage shall be tapped lightly prior to each reading.

(*g*) These operations shall be continued for at least 20 min. to insure equilibrium. After this time if consecutive gage readings observed are constant, the value of the readings shall be recorded as the "uncorrected vapor pressure" of the sample under test.

(*h*) The pressure gage shall be immediately removed from the bomb and its reading at the "uncorrected vapor pressure" compared with that of a mercury column. The correction thus determined shall be recorded as the "gage correction."

TABLE I.—CORRECTIONS TO CONVERT UNCORRECTED VAPOR PRESSURES TO REID VAPOR PRESSURES.

INITIAL AIR TEMPERATURE,[a] DEG. FAHR.	CORRECTIONS IN POUNDS PER SQUARE INCH FOR VARIOUS TEMPERATURES AS CALCULATED FOR NORMAL BAROMETRIC PRESSURES OF:				
	760 MM.	745 MM.	700 MM.	650 MM.	600 MM.
32	−2.9	−2.9	−2.7	−2.6	−2.5
40	−2.6	−2.6	−2.4	−2.3	−2.2
50	−2.2	−2.2	−2.1	−2.0	−1.9
60	−1.8	−1.8	−1.7	−1.6	−1.6
70	−1.4	−1.4	−1.3	−1.3	−1.2
80	−1.0	−1.0	−1.0	−0.9	−0.9
90	−0.5	−0.5	−0.5	−0.5	−0.5
100	0	0	0	0	0
110	+0.6	+0.6	+0.5	+0.5	+0.5

$$\text{Correction Factor} = \frac{(P_a - P_t)(t - 100)}{460 + t} - (P_{100} - P_t)$$

where t = the air chamber temperature at beginning of test, deg. Fahr.
P_t = the vapor pressure of water, lb. per sq. in., at t °F.
P_{100} = the vapor pressure of water, lb. per sq. in., at 100 F.
P_a = the normal barometric pressure in lb. per sq. in. at place where test is conducted.

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[a] For intermediate air temperatures, the corrections should be interpolated to the nearest 0.1 lb. per sq. in.

Calculations

18. (*a*) To calculate the "Reid vapor pressure" of the sample under test, the "uncorrected vapor pressure" (Section 17 (*g*)) must be corrected for the pressure-gage error (Section 17 (*h*)) and for the change in the pressure of the water vapor and air in the air chamber due to the differences between the "initial air temperature" and the temperature of the water bath. Table I shows the corrections to apply for "initial air temperatures" ranging from 32 to 110 F. The value resulting from the application of these corrections shall be recorded as the "Reid vapor pressure."

Example.—If the "uncorrected vapor pressure" is 11.6 lb. and the mercury column reads 11.8 lb. when the gage reading is 11.6 lb. the "gage correction" is +0.2 lb. If the "initial air temperature" is 82 F. the correction (see Table I, Column 2) for air temperature is −0.9 lb. for Reid-vapor-pressure determinations at an atmospheric pressure of 745 mm. The combined correction is −0.7 lb. The "Reid vapor pressure" is 11.6 lb. minus 0.7 lb., or 10.9 lb.

(*b*) Because of the fact that the atmospheric pressure provided (Section 16 (*h*)) for in the air chamber counteracts the external atmospheric pressure, the only pressure acting internally on the pressure gage is the absolute vapor pressure of the liquid in the bomb so that the gage reading is the absolute vapor pressure of the liquid in pounds per square inch at

100 F. For purposes of brevity the "Reid vapor pressure" shall be recorded in pounds, without reference to temperature used in the test or to unit of surface.

Accuracy

19. With proper care and attention to detail, duplicate results should not differ by more than 0.25 for gasolines having vapor pressures under 12 lb. nor by more than 0.5 lb. for other products.

TENTATIVE METHOD OF TEST
FOR
VISCOSITY BY MEANS OF THE SAYBOLT VISCOSIMETER[1]

A.S.T.M. Designation: D 88 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) This method shall be used for determining the Saybolt viscosity of petroleum products and lubricants.

(*b*) The Saybolt Universal Viscosimeter shall be used only for oils with times of flow of more than 32 sec. There is no maximum limit to viscosity to be measured by the Saybolt Universal Viscosimeter but, in general, liquids having an outflow time of the order of 1000 sec. and higher, Saybolt Universal, are tested more conveniently by means of the Saybolt Furol Viscosimeter.

(*c*) The Saybolt Furol Viscosimeter shall be used only for oils with times of flow of more than 25 sec. The outflow time of the Furol (Note) instrument is approximately one-tenth that of the Universal.

NOTE.—The word "Furol" is a contraction of the phrase "fuel and road oils."

Apparatus

2. The apparatus shall consist of an oil tube, bath, receiver, thermometers, timer, and withdrawal tube, conforming to the requirements specified in the following Paragraphs (*a*) to (*g*):

(*a*) *Oil Tube.*—The oil tube (illustrated in Fig. 1) shall be entirely of corrosion-resistant metal, with or without plating, and shall conform to the dimensional requirements shown in Table I within the permissible variations prescribed. The lower end of the oil tube shall be provided with a nut for locking it in place in the bath and with a cork or other suitable device to prevent flow until the test is started. For convenience a string or its equivalent may be attached to the cork for rapid removal.

The oil tube shall be standardized, and any correction in excess of 0.2 per cent shall be applied. The time of flow shall be within ±1 per cent (Note 1) of the time as obtained with the National Bureau of Standards' master Saybolt oil tube (Note 2).

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

This tentative method is in effect a tentative revision of, and **is intended** to supersede when adopted as standard, the present Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88 - 33), 1933 Book of A.S.T.M. Standards, Part II, p. 880.

NOTE 1.—For routine testing, oil tubes having corrections as high as ±2 per cent may be employed, provided, however, that any new oil tubes obtained after the adoption of this method shall not have corrections higher than ±1 per cent. For referee testing, oil tubes having corrections higher than ±1 per cent shall not be employed.

The oil tube may be standardized by any one of the following methods:

(*a*) Determination of outflow time for American Petroleum Institute oil standard and application of appropriate correction to obtain established value for the oil standard.

(*b*) Calibration by National Bureau of Standards subsequent to January 1, 1935.

(*c*) Comparison with a tube certified by the National Bureau of Standards subsequent to January 1, 1935, provided the tube shows no evidence of damage or injury since certification.

NOTE 2.—This tube, conforming to the A.S.T.M. dimensional specifications, has outflow times calibrated against oil standards under the maintenance of the American Petroleum Institute Committee on Viscosity Standards.

TABLE I.—DIMENSIONS OF OIL TUBES.

Dimensions	Saybolt Universal Viscosimeter			Saybolt Furol Viscosimeter		
	Minimum, cm.	Normal, cm.	Maximum, cm.	Minimum, cm.	Normal, cm.	Maximum, cm.
Inside diameter of outlet tube	0.1750	0.1765	0.1780	0.313	0.315	0.317
Outside diameter of outlet tube at lower end	0.28	0.30	0.32	0.40	0.43	0.46
Length of outlet tube[a]	1.215	1.225	1.235	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube[a]	12.40	12.50	12.60	12.40	12.50	12.60
Outside diameter of overflow rim, at the top[a, c]	[b]	....	3.30	[b]	....	3.30
Diameter of container[a]	2.955	2.975	2.995	2.955	2.975	2.995
Depth of cylindrical part of container[a]	8.8	....	....	8.8	....	....
Diameter of container between bottom of cylindrical part of container and top of outlet tube[a]	0.9	....	....	0.9	....	....

[a] This dimension is identical in the Saybolt Universal and the Saybolt Furol instruments.

[b] The minimum value shall preferably be not less than 3.2 cm.

[c] The section of overflow rim shall be bounded by straight lines, except that a fillet is permissible at the junction with the bottom of the gallery.

(*b*) *Bath.*—The bath shall serve as a support to hold the oil tube in a vertical position and as a container for the bath liquid. The bath shall be equipped with a stirring device and with means for heating or cooling. The source of heat or refrigeration shall be more than 1¼ in. (3 cm.) from the oil tube. If an external heater is used it must be more than 2 in. (5 cm.) from the oil tube.

The bath temperature necessary to maintain thermal equilibrium (while the oil in the oil tube is well stirred by the oil-tube thermometer) shall be within ±0.1 F. (0.06 C.) of the standard temperatures of 70 F. (21.1 C.) or 77 F. (25 C.) or shall not exceed 100.25, 122.35, 130.5, 141.0, 181.5 or 212.0 F. (37.9, 50.2, 54.7, 60.6, 83.1 or 100.0 C.), respectively, for the standard temperatures mentioned in Section 3. The level of the bath liquid shall not be lower than ¼ in. (0.5 cm.) above the overflow rim of the oil tube. For referee testing the bath liquid must be one which in the bath used will meet the preceding bath-temperature conditions (Note).

NOTE.—These temperature requirements can be met with water, aqueous solutions, and some baths with oil. In routine testing oil is generally used as the bath medium. This is allowable provided the temperature of the oil bath is adjusted so that the necessary condition of thermal equilibrium is maintained. It may be necessary to maintain the oil bath at slightly higher temperatures than those specified in the preceding paragraph. Temperature differentials between oil bath and oil tube necessary to maintain thermal equilibrium may be double those given above.

(*c*) *Receiver.*—The receiving flask (see Fig. 2) shall be of glass with a capacity up to the graduation mark on its neck of 60 ml. ± 0.05 ml. at 68 F. (20 C.). At the graduation mark, the inside diameter of the neck of the flask shall be 1 cm. ± 0.1 cm. The cylindrical portion of the neck of the flask shall extend not less than 0.3 cm. above and below the graduation mark. The graduation mark shall be 5.8 cm. ± 1.0 cm. above the bottom of the flask. The maximum outside diameter shall be less than 5.5 cm.

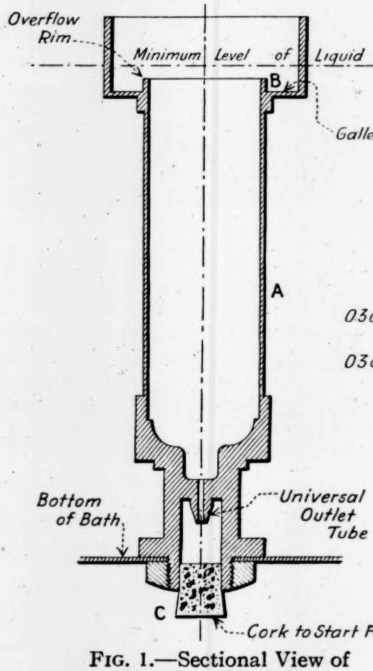
Overflow Rim
Minimum Level of Liquid in Bath
B
Gallery to be Drained before Starting Flow
A
Bottom of Bath
Universal Outlet Tube
C
Cork to Start Flow

FIG. 1.—Sectional View of Standard Oil Tube.

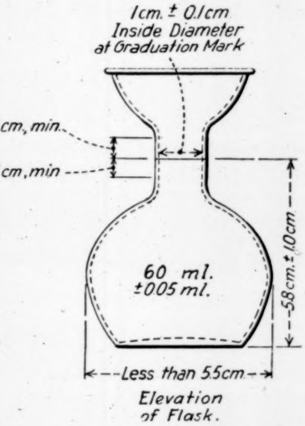
1cm. ± 0.1cm Inside Diameter at Graduation Mark
0.3cm, min.
0.3cm, min
60 ml. ±0.05 ml.
5.8cm. ± 1.0cm
Less than 5.5cm
Elevation of Flask.

FIG. 2.—Receiving Flask. This type of flask is recommended as convenient and durable.)

(*d*) *Oil-Tube Thermometers.*—The oil-tube thermometers shall conform to the following requirements. They shall include two sets of six thermometers each, one set being graduated in Fahrenheit degrees and the other in Centigrade degrees, the ranges being chosen to include the temperatures commonly used in testing. To prevent contact of the thermometer with the orifice in the oil tube a suitable support shall be attached to the enlargement of the thermometer stem.

Type: Etched stem, glass.
Liquid: Mercury.

Ranges and Subdivisions:

Range 66 to 80 F., subdivisions in 0.2 F. for tests at 70 and 77 F.
" 94 to 108 F., " " " " " " 100 F.
" 120 to 134 F., " " " " " " 122 and 130 F.
" 134 to 148 F., " " " " " " 140 F.
" 174 to 188 F., " " " " " " 180 F.
" 204 to 218 F., " " " " " " 210 F.

or

Range 19 to 27 C., subdivisions in 0.1 C. for tests at 21.1 and 25 C.
" 34 to 42 C., " " " " " " 37.8 C.
" 49 to 57 C., " " " " " " 50 and 54.4 C.
" 57 to 65 C., " " " " " " 60 C.
" 79 to 87 C., " " " " " " 82.2 C.
" 95 to 103 C., " " " " " " 98.9 C.

Total Length: 252 to 256 mm. (9.92 to 10.08 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm. (0.236 to 0.275 in.). The stem shall be made with an enlargement not less than 4 nor more than 7 mm. (0.16 to 0.28 in.) in length, having a diameter 2 to 3 mm. (0.08 to 0.12 in.) greater than that of the stem, the bottom of the enlargement being 114 mm. (4.5 in.) above the bottom of the bulb.

Bulb: Corning normal or equally suitable thermometric glass.
Length, 25 to 35 mm. (1.0 to 1.4 in.).
Diameter, not less than 5 mm. (0.197 in.) and not greater than that of stem.

Distance to Lowest Specified Graduation from Bottom of Bulb: 135 to 150 mm. (5.3 to 5.9 in.).

Distance to Highest Specified Graduation from Top of Thermometer: 20 to 35 mm. (0.8 to 1.4 in.).

Contraction Chamber: To be of long narrow type, top to be not more than 60 mm. (2.36 in.) above bottom of bulb, mercury to stand in contraction chamber at 32 F. (0 C.).

Expansion Chamber: To permit heating the thermometer 90 F. (50 C.) above highest temperature on scale, and in all cases to permit heating to 212 F. (100 C.).

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures and letters clear cut and distinct. They shall be in black except for the special markings below. The first and each succeeding 1 F. or 0.5 C. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 F. or 1 C.

Immersion: Total.

Special Marking: The test temperatures specified in Section 3 shall be shown in full at the appropriate points on the thermometer scale; the graduations corresponding to the test temperatures and the numbers to be in red. A serial number and the manufacturer's name or trade mark shall be etched on the stem.

Scale Error: The error at any point of the scale shall not exceed 0.2 F. (0.1 C.).

Standardization: The thermometers are to be standardized for the condition of total immersion. Correction for emergent stem shall not be applied.

Case: Each thermometer shall be supplied in a suitable case on which shall appear the marking, "A.S.T.M., Saybolt Viscosimeter Thermometer" and the range.

Note.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.
The diameter is that measured with a ring gage.
The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.
The top of the thermometer is the top of the finished instrument.

(*e*) *Bath Thermometers.*—Oil-tube thermometers, or other means for measuring temperature of at least equal accuracy, shall be used in the bath.

(*f*) *Timer.*—The stop watch or other timing device used shall be graduated in divisions of 0.2 sec. or less, and shall be accurate to within 0.1 per cent when tested over a 60-min. period (Note).

NOTE.—Electrical timing devices are permissible provided they are accurate and capable of being read to 0.2 sec. Timing devices actuated by synchronous motors shall be used only on electric circuits of controlled frequency.

(*g*) *Withdrawal Tube.*—The tube or pipette used for draining the gallery shall have a smooth tip of about 3 mm. outside diameter and about 2 mm. inside diameter.

Temperature of Testing

3. (*a*) With the Saybolt Universal Viscosimeter, determinations shall be made at 70, 100, 130 or 210 F. (21.1, 37.8, 54.4 or 98.9 C.).

(*b*) With the Saybolt Furol Viscosimeter, determinations shall be made at 77, 100, 122 or 210 F. (25, 37.8, 50 or 98.9 C.). In tests on road and paving materials, determinations may also be made at 140 and 180 F. (60 and 82.2 C.).

Procedure

4. (*a*) Viscosity determinations shall be made in a room free from drafts and rapid changes in temperature. For standardization and referee tests the room shall be between 68 and 86 F. (20 and 30 C.) and the actual temperature shall be recorded. For routine tests, temperatures up to 100 F. may be employed without introducing errors in excess of 1 per cent. Determinations shall not be made at temperatures below the dew point of the atmosphere surrounding the instrument.

(*b*) The oil tube shall first be cleaned with an effective solvent, such as benzol, and excess solvent shall be removed from the gallery.

(*c*) All oil shall be passed through a 100-mesh wire strainer before it is introduced into the oil tube. After the tube is cleaned, a quantity of the oil to be tested, sufficient to wet the entire surface of the tube, shall be poured into the tube and allowed to drain out (Note). The cork stopper shall be inserted not less than $\frac{1}{4}$ in. nor more than $\frac{3}{8}$ in. into the lower end of the air chamber at the bottom of the oil tube. The cork shall fit tightly enough to prevent the escape of air, as evidenced by the absence of oil on the cork after it is withdrawn.

NOTE.—The plunger commonly supplied with the viscosimeter shall never be used on instruments maintained as standards.

(*d*) If the test temperature is above that of the room, the oil shall be heated to not more than 3 F. (1.7 C.) above the temperature of test and if the temperature is below that of the room, the oil shall be cooled to not more than 3 F. (1.7 C.) below the temperature of test. The oil shall be poured into the oil tube until it ceases to overflow into the gallery. The oil in the oil tube shall be kept well stirred with the oil-tube thermometer, care being taken to avoid hitting the outflow tube. The bath temperature shall be adjusted until the oil temperature remains constant. After thermal equilibrium has been attained no further adjustments shall be made in the bath temperature. The test results shall be discarded if the indicated bath temperature varies by more than ±0.05 F. (0.03 C.) in tests at 70, 77, 100, 122 and 130 F. (21.1, 25, 37.8, 50 and 54.4 C.) or by more than ±0.10 F. (0.06 C.) in tests at 140, 180 and 210 F. (60, 82.2 and 98.9 C.).

(*e*) After the temperature of the oil in the oil tube has remained constant within 0.02 F. (0.01 C.) of the desired temperature for 1 min. with constant stirring, the oil-tube thermometer shall be withdrawn and the surplus oil removed quickly from the gallery by means of the withdrawal tube so that the level of the oil in the gallery is below the level in the oil tube proper. The tip of the withdrawal tube shall be inserted at one point in the gallery. The test shall be started over again if the tip of the withdrawal tube touches the overflow rim (see Fig. 1). Under no conditions shall the excess oil be removed by rotating the withdrawal tube around the gallery.

(*f*) The receiving flask shall be placed in position so that the stream of oil from the outlet tube will strike the neck of the flask. The graduation mark on the receiving flask shall be not less than 10 cm. or more than 13 cm. from the bottom of the bath. The cork shall be snapped from its position and at the same instant the timer shall be started. The timer shall be stopped when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask.

Reporting Results

5. The time in seconds as determined by the prescribed procedure, with the proper calibration correction, is the Saybolt Universal (or Saybolt Furol) viscosity of the oil at the temperature at which the test is made. Results shall be reported to the nearest 0.1 sec. for viscosity values below 200 sec. and to the nearest whole second for values 200 sec. or above.

Accuracy

6. With proper attention to details of method of procedure, results in different laboratories with different operators under referee or standardization conditions of testing, should not differ by more than 0.5 per cent.

AMERICAN TENTATIVE STANDARD
A.S.A. No.: Z11.28-1935

TENTATIVE DEFINITIONS OF TERMS RELATING TO PETROLEUM[1]

A.S.T.M. Designation: D 288 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1928; REVISED, 1931, 1935.[2]

These definitions have been approved as
AMERICAN TENTATIVE STANDARD
by the American Standards Association

Benzine.—This term is archaic and misleading and should not be used.

Crude Petroleum.—A naturally occurring mixture, consisting predominantly of hydrocarbons, and/or of sulfur, nitrogen and/or oxygen derivatives of hydrocarbons, which is removed from the earth in liquid state or is capable of being so removed.

NOTE.—Crude petroleum is commonly accompanied by varying quantities of extraneous substances such as water, inorganic matter and gas. The removal of such extraneous substances alone does not change the status of the mixture as crude petroleum. If such removal appreciably affects the composition of the oil mixture, then the resulting product is no longer crude petroleum.

Crude Shale Oil.—The oil obtained as a distillate by the destructive distillation of oil-shale.

End Point.—The highest temperature reading observed on the distillation thermometer during the distillation procedure conducted in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) and the Standard Method of Test for Distillation of Natural Gasoline (A.S.T.M. Designation: D 216) of the American Society for Testing Materials.

Engine Distillate.—A refined or unrefined petroleum distillate similar to naphtha, but often of higher distillation range.

Fuel Oil.—Any liquid or liquefiable petroleum product burned for the generation of heat in a furnace or firebox, or for the generation of power in an engine, exclusive of oils with a flash point below 100° F., Tag closed tester, and oils burned in cotton or wool-wick burners. Fuel oils in common use fall into one of four classes: (1) residual fuel oils, which are topped crude petroleums or viscous residuums obtained in refinery operations; (2) distillate fuel oils, which are distillates derived directly or indirectly from crude petroleum; (3) crude petroleums and weathered crude petroleums of relatively low commercial value; (4) blended fuels, which are mixtures of two or more of the three preceding classes.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee D-2 on Petroleum Products and Lubricants.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

Gas Oil.—A liquid petroleum distillate having a viscosity intermediate between that of kerosine and lubricating oil.

NOTE.—It should be understood that oils, other than gas oil as defined above, may be and are used in the manufacture of gas.

Gasoline.—A refined petroleum naphtha which by its composition is suitable for use as a carburant in internal combustion engines.

Kerosine.—A refined petroleum distillate having a flash point not below 73° F. (23° C.), as determined by the Abel Tester (which is approximately equivalent to 73° F. (23° C.) as determined by the Tag Closed Tester, A.S.T.M. Standard Method D 56) and suitable for use as an illuminant when burned in a wick lamp.

NOTE.—In the United States of America local ordinances or insurance regulations require flash points higher than 73° F. (23° C.), Tag Closed Tester.

Oil-Shale.—A compact rock of sedimentary origin, with an ash content of more than 33 per cent and containing organic matter that yields oil when destructively distilled but not appreciably when extracted with the ordinary solvents for petroleum.

Petroleum Lubricating Grease.—A combination of a petroleum product and a soap or a mixture of soaps, suitable for certain types of lubrication.

Petroleum Naphtha.—A generic term applied to refined, partly refined or unrefined petroleum products and liquid products of natural gas, not less than 10 per cent of which distills below 347° F. (175° C.) and not less than 95 per cent of which distills below 464° F. (240° C.), when subjected to distillation in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.

NOTE.—The "naphthas" used for specific purposes such as cleaning, manufacture of rubber, manufacture of paints and varnishes, etc., are made to conform to specifications which may require products of considerably greater volatility than that set by the limits of this generic definition.

Petroleum Spirits (White Spirits).—A refined petroleum distillate with a minimum flash point of 70° F. (21° C.) determined by the Tag Closed Tester in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids (A.S.T.M. Designation: D 56) of the American Society for Testing Materials or by the Abel Tester, with volatility and other properties making it suitable as a thinner and solvent in paints, varnishes and similar products.

NOTE.—The term "turpentine substitute" as applied to petroleum spirits is to be condemned as false and misleading. The term "mineral spirits" which is frequently used in the paint and varnish industry is a misnomer as it includes within its scope not only petroleum products, but other hydrocarbon mixtures, such as coal-tar distillates. In Great Britain the term "petroleum spirits" is applied to a very light hydrocarbon mixture having a flash point below 32° F. (0° C.).

Pitch.—This term shall not be applied to petroleum products.

Tar.—This term shall not be applied to petroleum products.

Topped Crude Petroleum.—A residual product remaining after the removal, by distillation, or other artificial means, of an appreciable quantity of the more volatile components of crude petroleum.

Tops.—The unrefined distillate obtained in topping a crude petroleum.

Weathered Crude Petroleum.—The product resulting from crude petroleum through loss, due to natural causes, during storage and handling, of an appreciable quantity of the more volatile components.

AMERICAN ASSOCIATION STATE
HIGHWAY OFFICIALS STANDARD
A.A.S.H.O. No.: T-59

TENTATIVE METHODS OF TESTING EMULSIFIED ASPHALTS[1]

A.S.T.M. Designation: D 244 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1926; Revised, 1928, 1933, 1934, 1935.

Scope

1. These methods are intended for the examination of asphalt emulsions composed, principally, of a semisolid or liquid asphaltic base, water and an emulsifying agent.

VISCOSITY

2. The viscosity of emulsified asphalt shall be determined by means of the Saybolt Furol viscosimeter.

Apparatus

3. The following apparatus will be required:

(*a*) *Viscosimeter.*—A Saybolt Furol viscosimeter conforming to the requirements specified in the Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[2]

(*b*) *Sieve.*—A No. 20 sieve of the U. S. Standard Sieve Series, of iron wire cloth, framed or unframed, optional, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3]

Procedure

4. (*a*) The viscosity determination shall be made at 77 F. (25 C.) and shall be expressed in seconds, Saybolt Furol, being the time in seconds for the delivery of 60 ml. of emulsion.

(*b*) While the Saybolt Furol viscosimeter is not used for petroleum products and lubricants when the time of flow is less than 25 sec., this instrument is satisfactory for testing emulsified asphalt when the time of flow is not less than 20 sec.

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[1] Under the standardization procedure of the Society, these methods are under the joint jurisdiction of A.S.T.M. Committee D-4 on Road and Paving Materials and Committee D-8 on Bituminous Waterproofing and Roofing Materials

[2] 1933 Book of A.S.T.M. Standards Part II, p. 880.

[3] *Ibid.*, p. 1244.

(*c*) *Preparation of Sample.*—The sample shall be stirred thoroughly without incorporating bubbles in it and then poured into a 4-oz. bottle. The bottle shall then be placed in the water bath at 77 F. (25 C.) for 30 min. and the sample then mixed in the bottle by inverting several times, slowly enough to prevent bubble formation. The sample shall then be poured into the viscosity tube through a 20-mesh strainer, allowing a small portion to flow through the outlet tube to waste. The cork shall then be placed in position, the tube filled and without again stirring the sample the viscosity shall be determined as described in the Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88) of the American Society for Testing Materials.[1]

DISTILLATION

Apparatus

5. The following apparatus will be required:

(*a*) *Iron Still.*—The iron still shall be approximately 6 by 3½ in. in inside diameter with adjustable ring burner with holes on the inner periphery to fit around the outside of the still.

NOTE.—A modification of this still is shown in Fig. 2. It consists of the regular still with an expansion chamber superimposed thereon. Two additional ring burners are required, one approximately 6 in. in inside diameter with the holes bored on the inside periphery, and one approximately 2 in. in diameter with the holes bored on top.

(*b*) *Connecting Apparatus.*—A connecting tube, tin shield, condenser trough, condenser tube and graduated cylinder, as shown in Fig. 1.

(*c*) *Thermometer.*—A thermometer graduated from 30 to 580 F. (0 to 300 C.), conforming to the requirements of the Low-Distillation Thermometer specified in the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[2]

NOTE.—The details of the assembly of apparatus for the distillation test are illustrated in Fig. 1.

Procedure

6. (*a*) Exactly 200 g. of a well-mixed and representative sample of the emulsion shall be placed in the previously weighed iron still (including lid, clamp, thermometer and gasket, if gasket is used).

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 880.

[2] 1935 Supplement to Book of A.S.T.M. Standards, p. 177.

(*b*) A gasket of oiled paper may be used between the still and its cover or the joint ground to a tight fit. The cover shall be clamped securely on the still.

(*c*) The thermometer shall be inserted through the small hole in the cover, using a cork stopper, so that the end of the bulb is ¼ in. from the bottom of the still.

(*d*) The ring burner shall be placed around the still and the heat applied by this means to the top of the still. Just enough heat from a bunsen burner shall also be applied to the connecting tube to prevent condensation of water in this tube.

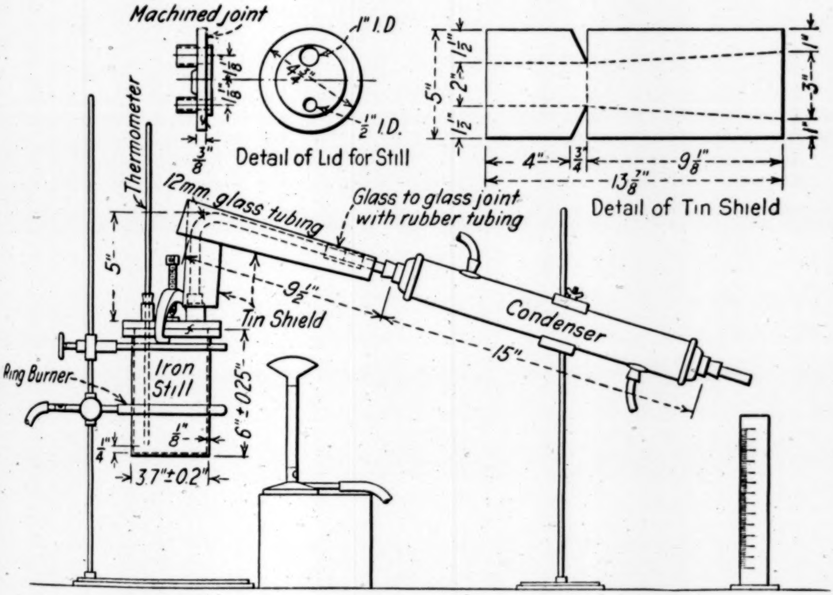

Machined joint
1" I.D
4½"
½" I.D.
⅛"
⅛"
⅜"
Detail of Lid for Still
5"
1½"
2"
1½"
4"
¾"
9⅛"
13⅞"
1"
3"
1"
Detail of Tin Shield
Thermometer
12mm. glass tubing
Glass to glass joint with rubber tubing
5"
9½"
Tin Shield
Condenser
15"
Ring Burner
Iron Still
6"±0.25"
⅛"
¼"
3.7"±0.2"

FIG. 1.—Apparatus Assembly for Distillation Test of Emulsified Asphalts.

(*e*) After practically all the condensate has been removed from the still and the temperature of the residue has reached 250 F. (121 C.), the position of the heat from the ring burner shall be lowered to midway of the still and held there until the thermometer reaches 349 F. (176 C.). The burner shall then be rapidly lowered to within ½ in. of the bottom of the still and the temperature increased to and maintained at 500 F. (260 C.) for 15 min. This latter period of heating is necessary to insure a smooth homogeneous residue in the still.

(*f*) At the expiration of the heating period at the maximum temperature, the still and accessories shall again be weighed as described in Paragraph (*a*) and the percentage residue calculated and reported. The cover shall then be removed from the still and suitable portions of the residue shall be poured immediately into suitable molds and containers for making the required tests. The residue in the molds and containers shall be permitted to cool, uncovered, to laboratory room temperature and thereafter tested as described in Sections 26 to 30, inclusive.

NOTE.—When it appears impossible to distill an emulsified asphalt in the still described in Section 5 (*a*) due to excessive foaming of the emulsion, then the modified still shown in Fig. 2 should be substituted for the still shown in Fig. 1 and the following procedure followed: Place the 6-in. burner around the larger diameter of the still near its top. This serves as a support. Place the 4-in. burner immediately beneath the flare and the 2-in. burner not less than 2 in. below the bottom. Distillation is started with only the 2-in. burner lighted. Practically all of the distillate should be over in about 45 min. When the distillation apparently stops, light the two larger ring burners and adjust to a low flame. Distillation resumes and when it stops again increase the heat by adjusting the flame of the 2-in. burner. When the temperature can be read upon the thermometer, increase the rate of heating by raising the flame on both the 2 and 4-in. burners and bring the temperature to 500 F. (260 C.).

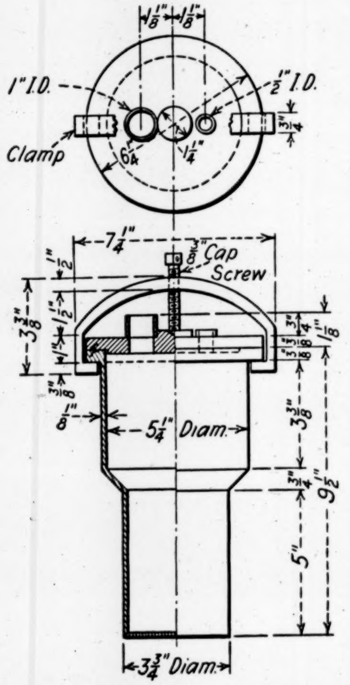


FIG. 2.—Iron Still for Use with Badly Foaming Emulsions.

If any evidence is noted of the emulsion beginning to foam over in the delivery tube, remove the 2-in. burner quickly and raise a pan of water so as to immerse the still bottom to a depth of about 2 in. for a moment which will check the foaming. Upon resumption of heating watch delivery tube carefully and repeat treatment if necessary.

When the residue has reached and remained at 500 F. (260 C.) for 15 min., proceed as described in Section 6 for the regular still. While the distillation should be completed in not less than 1 hr. nor more than 1¼ hr. from the first application of heat to the still, the maximum stated is not mandatory as a longer time may be required in some cases to avoid foaming of the emulsion into the condenser.

If the residue in the still prior to pouring the ductility and penetration specimens appears granular or heterogeneous in any way, stir with a spatula until the material runs from the spatula in strings instead of drops, and then pour. Should the residue then appear granular and heterogeneous, the test shall be rejected and the distillation repeated as previously described with the exception that the still temperature at 500 F. (260 C.) shall be maintained for a longer time than 15 min. until the desired condition of the residue is obtained.

DETERMINATION OF WATER

Scope

7. This method of test determines water existing in a sample of bituminous emulsion by distilling the sample with a volatile solvent.

Apparatus

8. (*a*) The apparatus shall consist of a metal still or glass flask, heated by suitable means and provided with a reflux condenser discharging into a trap connected to the still or flask. The trap serves to collect and measure the condensed water and to return the solvent to the still. The type of distilling apparatus used is not an essential feature of this method.

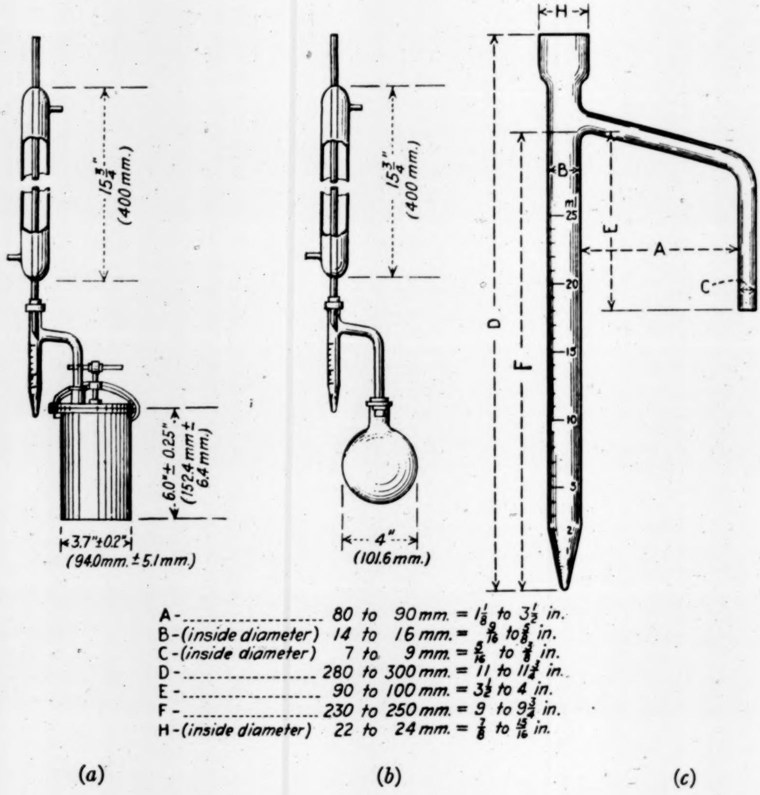
(*b*) *Metal Still.*—The metal still, Fig. 3 (*a*), shall be a vertical cylindrical vessel, preferably of copper, having a faced flange at the top to which the head is tightly attached by means of a clamp. The head shall be of metal, preferably of brass or copper, and be provided with a tubulation 1 in. in inside diameter.

(*c*) *Glass Still.*—The glass flask, Fig. 3 (*b*), shall be of the short neck, round-bottom type, made of well-annealed glass, having an approximate capacity of 500 ml.

(*d*) *Heat Source.*—The burner used with the metal still shall be a ring gas burner 100 mm. (4 in.) in inside diameter. With the glass flask, an ordinary gas burner or electric heater may be used as the source of heat.

(*e*) *Condenser.*—The condenser shall be of the water-cooled, reflux, glass-tube type, having a condenser jacket not less than 400 mm. (15¾ in.) in length with an inner tube 9.5 to 12.7 mm. (⅜ to ½ in.) in outside diameter. The end of the condenser to be inserted in the trap shall be ground off at an angle of 30 deg. from the vertical axis of the condenser.

(*f*) *Trap.*—The trap shall be made of well-annealed glass constructed in accordance with Fig. 3 (*c*) and shall be graduated from 0 to 25 ml. The tube shall be graduated from 0 to 2 ml. in 0.1 ml., from 2 to 5 ml. in 0.2 ml., and from 5 to 25 ml. in 0.5 ml. The outside diameters should be preferably 2.5 to 3.5 mm. ($\frac{3}{32}$ to $\frac{1}{8}$ in.) greater than the inside diameters specified.



A-	80	to	90 mm.	= $1\frac{1}{8}$ to $3\frac{1}{2}$ in.
B-(inside diameter)	14	to	16 mm.	= $\frac{9}{16}$ to $\frac{5}{8}$ in.
C-(inside diameter)	7	to	9 mm.	= $\frac{5}{16}$ to $\frac{3}{8}$ in.
D-	280	to	300 mm.	= 11 to $11\frac{3}{4}$ in.
E-	90	to	100 mm.	= $3\frac{1}{2}$ to 4 in.
F-	230	to	250 mm.	= 9 to $9\frac{3}{4}$ in.
H-(inside diameter)	22	to	24 mm.	= $\frac{7}{8}$ to $\frac{15}{16}$ in.

(*a*) (*b*) (*c*)

FIG. 3.—Apparatus for Determining Water.

Solvent

9. The solvent used when testing bituminous emulsions shall be a coal-tar naphtha or a light oil and shall conform to the following distillation requirements, determined in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine,

and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials:[1]

98 per cent shall distill between 248 F. (120 C.) and 482 F. (250 C.).

Sample

10. The sample shall be thoroughly representative of the material to be tested and the portion of the sample used for the test shall be thoroughly representative of the sample itself. Deviation from this requirement shall not be permitted.

NOTE.—The difficulties in obtaining proper representative samples for this determination are unusually great so that the importance of sampling cannot be too strongly emphasized.

Procedure

11. (*a*) When the material to be tested contains less than 25 per cent of water, exactly a 100-g. sample shall be placed in the still or flask. When the material contains more than 25 per cent of water, the sample shall be 50 g. The sample to be tested shall be thoroughly mixed with an equal volume of solvent by swirling, proper care being taken to avoid any loss of material.

(*b*) The connections between the still or flask, trap and condenser shall be made by means of tight-fitting corks as shown in Fig. 3 (*a*) and (*b*). The end of the condenser inserted in the trap shall be adjusted to that position which will allow the end to be submerged to a depth of not more than 1 mm. (0.04 in.) below the surface of the liquid in the trap after distillation conditions have been established. When the metal still is used, a heavy paper gasket moistened with the solvent shall be inserted between the lid and flange before attaching the clamp. A loose cotton plug shall be inserted in the top of the condenser tube to prevent condensation of atmospheric moisture in the condenser tube.

(*c*) Heat shall then be applied and so regulated that the condensed distillate falls from the end of the condenser at the rate of from 2 to 5 drops per sec. The ring burner used with the metal still shall be placed about 3 in. above the bottom of the still at the beginning of the distillation and gradually lowered as the distillation proceeds.

(*d*) The distillation shall be continued at the specified rate until no water is visible on any part of the apparatus except at the bottom of the trap. This operation usually requires less than 1 hr. A persistent ring of condensed water in the condenser tube shall be removed by increasing the rate of distillation for a few minutes.

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[1] 1935 Supplement to Book of A.S.T.M. Standards, p. 177.

Calculation and Reporting of Results

12. The volume of condensed water measured in the trap at room temperature multiplied by 100 and divided by the weight of sample used, shall be the percentage of water and shall be reported as "...... per cent water by weight, A.S.T.M. method."

Accuracy

13. The accuracy to be expected with this method is that duplicate determinations of water should not differ from each other by more than one division on the trap.

SETTLEMENT

Apparatus

14. The following apparatus will be required:

(*a*) *Cylinders.*—Two glass cylinders of 500-ml. capacity with pressed or molded glass base and cork or glass stoppers. The outside diameter shall be 5.0 cm. ±0.5 cm. and the cylinders shall be graduated at each 5-ml. interval to the 500-ml. mark.

(*b*) *Glass Pipette.*—A syphon, glass tube pipette, 60-ml. capacity, form optional.

Procedure

15. (*a*) A 500-ml. sample, representative of the emulsion, shall be placed in each of two glass cylinders. The cylinder shall be stoppered air-tight and stood aside unmolested, at laboratory air temperature for 5 days. After standing for this 5-day period, approximately the first 55 ml. of emulsion shall be removed by means of the pipette or syphon from the top of each cylinder without disturbing the balance of their contents. Exactly 50 g. of each of the two samples, after each has been thoroughly mixed separately, shall be weighed into separate 600-ml. low-form glass beakers and the asphaltic residue determined by evaporation at 325 F. (163 C.) for 3 hr. in the apparatus described in the Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (A.S.T.M. Designation: D 6) of the American Society for Testing Materials.[1]

(*b*) After removal of the first sample, approximately the next 390 ml. shall be syphoned off from each of the cylinders. The residue remaining in the cylinders shall be mixed thoroughly and exactly 50 g. shall be weighed out from each of them and the amount of asphaltic residue (all sediment, if any, included) shall be determined by evaporation as described in Paragraph (*a*) for the two top samples.

(*c*) The numerical difference between the average percentage of asphaltic residue from the two top samples and the average percentage found in the two bottom samples shall be recorded.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 962.

DEMULSIBILITY

Apparatus and Reagents

16. The following apparatus and reagents will be required:

(*a*) *Sieves.*—Three No. 14 sieves of the U. S. Standard Sieve Series, of iron wire cloth, unframed, approximately 5-in. square, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1]

(*b*) *Beakers.*—Three glass beakers of 600-ml. capacity each.

(*c*) *Glass Rods.*—Three glass rods, rounded ends, approximately $\frac{5}{16}$ in. in diameter.

(*d*) *Burette.*—A 50-ml. glass burette graduated in 0.1 ml.

(*e*) *Calcium Chloride Solution (0.02 N).*

(*f*) *Calcium Chloride Solution (0.10 N).*

Procedure

17. (*a*) The percentage of residue shall be determined by distillation as described in Section 6.

(*b*) The weight of each assembly of beaker, rod and sieve shall be recorded.

(*c*) Exactly 100 g. of the emulsified asphalt shall be weighed into each of three 600-ml. tared beakers. Over a period of approximately 2 min., 35 ml. of 0.02 N $CaCl_2$ solution (if quick-setting emulsion is being tested) or 50 ml. of 0.10 N $CaCl_2$ solution (if mixing type emulsion is being tested) shall be added to each beaker from a burette. While adding the solution of $CaCl_2$, the contents of the beaker shall be stirred continuously and vigorously, kneading lumps against the sides of the beaker to insure thorough mixing of the reagent with the emulsion. This operation shall be performed after bringing the weighed sample of emulsion and the reagent to the standard temperature of 77 F. ± 1.0 F. (25 C. ± 0.5 C.).

(*d*) One of the wire sieves shall be fitted over a beaker or other suitable vessel and the mixture of emulsion and reagent poured through the sieve. The beaker, containing the sample and glass rod, shall be rinsed with distilled water. All lumps shall be kneaded and broken up and the washing of the beaker, rod and sieve shall be continued until there is no longer any appreciable color imparted to the wash water. After washing as directed, the beaker, rod and sieve used in each individual test shall be placed in a drying oven and dried at 325 F. (163 C.) to constant weight.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

Calculation

18. The total weight thus obtained less the total tare weight of the beaker, rod and sieve shall be the weight of the residue by the demulsibility test. The ratio of the average weight in grams from three tests of each individual sample of emulsified asphalt, A, to the weight in grams of residue per 100 g. of emulsion, B, obtained in the test for residue by distillation described in Section 6 multiplied by 100, shall be recorded as the percentage of demulsibility of the sample tested:

$$\text{Percentage Demulsibility} = \frac{A}{B} \times 100$$

SIEVE TEST

Apparatus and Reagents

19. The following apparatus and reagents will be required:

(*a*) *Sieve.*—A No. 20 sieve, 3-in. in diameter with metal frame, of the U. S. Standard Sieve Series, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1]

(*b*) *Pan.*—A tin box cover or shallow metal pan of appropriate size to fit over the bottom of the standard sieve.

(*c*) *Sodium Oleate Solution (2 per cent).*—Prepare a 2 per cent solution of pure sodium oleate in distilled water.

Procedure

20. The weight of the sieve and pan shall be recorded and the wire cloth of the No. 20 sieve shall then be wet with the sodium oleate solution (2 per cent). Exactly 1000 g. of the emulsified asphalt shall then be weighed and poured through the wire sieve, the container and the residue on the sieve being washed thoroughly with the sodium oleate solution until the washings run clear. The pan shall then be placed under the sieve and heated for 2 hr. in a drying oven whose interior temperature is 220 F. (105 C.), then cooled in a desiccator and weighed.

Calculation

21. The total weight of the sieve, pan, and residue in grams less the combined tare weight of the sieve and pan, is the weight of the residue by the sieve test. The percentage of residue in the emulsion shall be calculated on the basis of this weight.

MISCIBILITY WITH WATER

NOTE.—This test is not applicable to the so-called quick-setting type of emulsions.

Procedure

22. To about 50 ml. of the emulsion shall be gradually added about 150 ml. of distilled water, stirring the mixture while adding the

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

water. The temperature is not important but should be between 21 and 25 C. (70 and 77 F.). The mixture shall be allowed to stand for 2 hr. and then examined for any appreciable coagulation of the asphalt content of the emulsion.

COATING TEST

NOTE.—This test is applicable only for emulsions containing a base of asphalt of semisolid consistency. It is not applicable to the so-called quick-setting type of emulsions.

Apparatus and Reagents

23. The following apparatus and reagents will be required:

(*a*) *Screens.*—A standard $\frac{3}{4}$-in. screen and $\frac{1}{4}$-in. screen conforming to the requirements of the Standard Specifications for Round-Hole Screens for Testing Purposes (A.S.T.M. Designation: E 17) of the American Society for Testing Materials.[1]

(*b*) *Spatula.*—A steel spatula or its equivalent, blade approximately 8 in. in length.

(*c*) *Dish.*—A round-bottom, iron dish or a kitchen saucepan, approximately 1-qt. capacity.

(*d*) A supply of reference stone (hard limestone, trap rock, or other type) which has been washed with water and dried before using. The grading of this stone shall be such that it will all pass through a standard $\frac{3}{4}$-in. screen and not more than 5 per cent will pass through a $\frac{1}{4}$-in. screen.

NOTE.—Each laboratory shall select its own reference stone supply, the source of which is not apt to change. This is to obviate rapid changes in the character of reference stone used in any one laboratory.

Procedure

24. (*a*) Exactly 465 g. of the washed and dried graded stone, shall be weighed and placed in the metal pan.

(*b*) A 35-g. sample of the emulsion shall then be added to the stone in the pan and mixed vigorously with the spatula for 3 min.

(*c*) Record whether or not there is appreciable separation of the asphaltic base from the water of the emulsion and whether or not the stone is uniformly and thoroughly coated with the emulsion.

FREEZING TEST

Procedure

25. (*a*) Approximately 400 g. of the emulsion shall be placed in a clean metal container, such as a 1-pt. press-top tin.

(*b*) The emulsion in the closed container shall be exposed to a temperature of 0 F. (−17.7 C.) for twelve consecutive hours.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1242.

(*c*) At the expiration of the freezing period, the emulsion shall be permitted to thaw by exposure of the container to the temperature of the laboratory.

(*d*) After the first operation of freezing and thawing, the procedure shall be repeated twice, so that the emulsion will have been subjected to three cycles of freezing and thawing.

(*e*) After the third cycle, the emulsion may be homogeneous or may have separated into distinct layers which cannot be rendered homogeneous by stirring at laboratory temperature.

(*f*) The result of this test shall be reported as either "Homogeneous" or "Broken."

PENETRATION OF RESIDUE

26. The penetration shall be determined upon a representative portion of the residue in accordance with the Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5) of the American Society for Testing Materials.[1]

SOLUBILITY OF RESIDUE

27. The solubility in carbon disulfide shall be determined upon a representative portion of the residue in accordance with the Standard Method of Test for the Determination of Bitumen (A.S.T.M. Designation: D 4) of the American Society for Testing Materials.[2]

DUCTILITY OF RESIDUE

28. The ductility shall be determined upon a representative portion of the residue in accordance with the Standard Method of Test for Ductility of Bituminous Materials (A.S.T.M. Designation: D 113) of the American Society for Testing Materials.[3]

SPECIFIC GRAVITY OF RESIDUE

29. The specific gravity shall be determined upon a representative portion of the residue in accordance with the Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (A.S.T.M. Designation: D 70) of the American Society for Testing Materials.[4]

ASH IN RESIDUE

30. The ash shall be determined upon a representative portion of the residue in accordance with the Rapid Routine Method of Ash Determination, as described in the Standard Methods of Analysis of Grease (A.S.T.M. Designation: D 128) of the American Society for Testing Materials.[5]

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 971.

[2] *Ibid.*, p. 945.

[3] 1935 Supplement to Book of A.S.T.M. Standards, p. 194.

[4] 1933 Book of A.S.T.M. Standards, Part II, p. 1002.

[5] *Ibid.*, p. 827.

AMERICAN ASSOCIATION STATE
HIGHWAY OFFICIALS STANDARD
A.A.S.H.O. No.: T-56

TENTATIVE METHOD OF TEST
FOR
RESIDUE OF SPECIFIED PENETRATION[1]

A.S.T.M. Designation: D 243 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1926; REVISED, 1928, 1932, 1935.

Scope. 1. This method of test covers the determination of percentage of residue having a specified penetration at 100 g., 5 seconds, 25° C. (77° F.), obtained by heating a road oil or a semisolid asphalt having a penetration of more than 100, at a temperature of 249 to 260° C. (480 to 500° F.). When the penetration of the residue is not otherwise stated it shall be understood to be 100. The residue obtained is available for tests as desired.

APPARATUS

Apparatus. 2. The apparatus shall consist of a container, heating bath, hot plate, and thermometer, with necessary accessory apparatus.

Container. 3. The container in which the sample is to be tested shall be a flat-bottom, cylindrical seamless tin box, 70 mm. ($2\frac{3}{4}$ in.) in diameter and 45 mm. ($1\frac{3}{4}$ in.) in depth.

NOTE.—The American Can Co.'s 6-oz. gill style flat-bottom, seamless ointment box, deep pattern, fulfills these requirements.

Heating Bath. 4. (*a*) The heating bath shall be a cast-iron air-bath permitting the immersion of the container to a depth of $1\frac{1}{4}$ in. through an opening $\frac{1}{16}$ in. larger in diameter than the container. It shall support the container $\frac{1}{4}$ in. above the hot plate and with at least $\frac{1}{4}$ in. free air space between the sides of the container and of the air-bath below the opening. A suitable air-bath is shown in Fig. 1.

Hot Plate. (*b*) The air-bath shall be heated upon a suitably mounted hot plate, heated either electrically or by means of a gas flame. The plate shall be capable of maintaining the sample continuously at the required temperature, and apparatus necessary to fulfill this requirement, such as a rheostat or gas pressure regulator, shall be provided.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

Thermometer.

5. The thermometer shall conform to the following requirements.[1] These specifications cover a special thermometer graduated to either Centigrade or Fahrenheit degrees as specified, the ranges being −6 to +400° C., or +20 to +760° F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −6 to +400° C. in 2° C. or +20 to +760° F. in 5° F.

TOTAL LENGTH: 303 to 307 mm. (11.92 to 12.08 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, not over 13 mm. (0.51 in.).
Diameter, not greater than stem.

DISTANCE TO −6° C. OR 20° F. LINE FROM BOTTOM OF BULB: 40 to 50 mm. (1.57 to 1.97 in.)

DISTANCE TO 400° C. OR 760° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Red glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10° F. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20°.

IMMERSION: 25 mm. or one inch. The words "1-in. immersion" on Fahrenheit thermometers or "25-mm. immersion" on Centigrade thermometers and a line around the stem 25.4 mm. or 1.00 in. above the bottom of the bulb shall be etched on the thermometer.

SPECIAL MARKING: "A.S.T.M. Open Flash" a serial number and the manufacturer's name or trade-mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 1° C. up to 372° C. or 2.5° F. up to 700° F.

STANDARDIZATION: The thermometer shall be standardized at the ice point and at intervals of approximately 100° F. for 25-mm. or 1-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
100° C.	200° F.	44° C.	110° F.
150° C.	300° F.	54° C.	129° F.
200° C.	400° F.	64° C.	150° F.
250° C.	500° F.	77° C.	175° F.
300° C.	600° F.	91° C.	205° F.
350° C.	700° F.	108° C.	240° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 to 370° C. or 680 to 700° F. for 24 hours, the accuracy shall be within the limit specified. The test shall be made under the immersion conditions specified for this thermometer.

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[1] These specifications are the same as for the open cup flash point thermometer specified in the Standard Method of Test for Flash and Fire Points by Means of Open Cup (A.S.T.M. Designation D 92), see 1933 Book of A.S.T.M. Standards, Part II, p. 800.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Open Flash, -6 to +400° C." or "A.S.T.M. Open Flash, +20 to +760° F.," according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

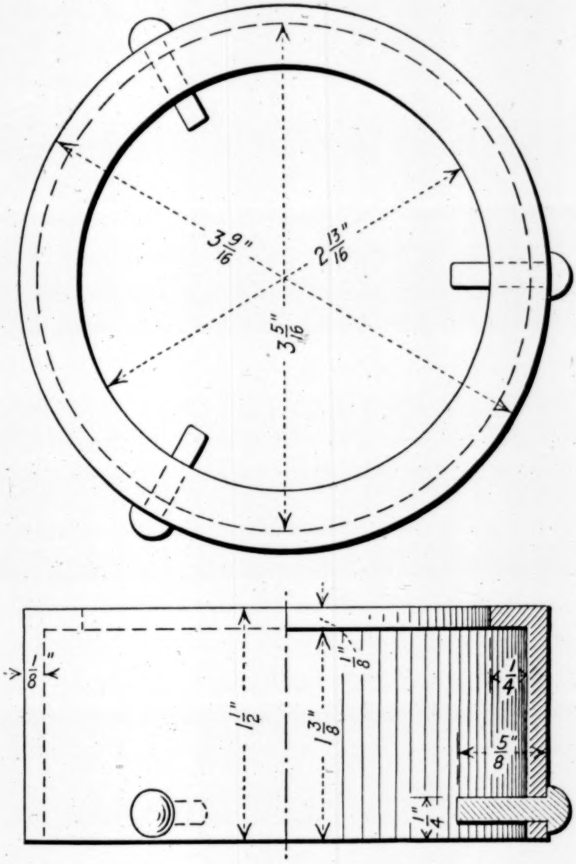

FIG. 1.—Cast-Iron Air-Bath.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PREPARATION OF SAMPLE

6. The sample as received shall be thoroughly stirred and agitated, to insure a complete mixture before the portion for testing is removed. **Preparation of Sample.**

PROCEDURE

Procedure. 7. One hundred grams (100.00 ± 0.10 g.) of the material to be tested shall be weighed into a tared container, which shall then be placed in the air-bath in position to be heated. The thermometer shall be supported in the sample equidistant from the sides of the container and with the bottom of the bulb neither more than $\frac{1}{4}$ in. above nor touching the bottom of the container. The bulb shall be completely immersed in the sample throughout the heating. An assembly of the apparatus is shown in Fig. 2.

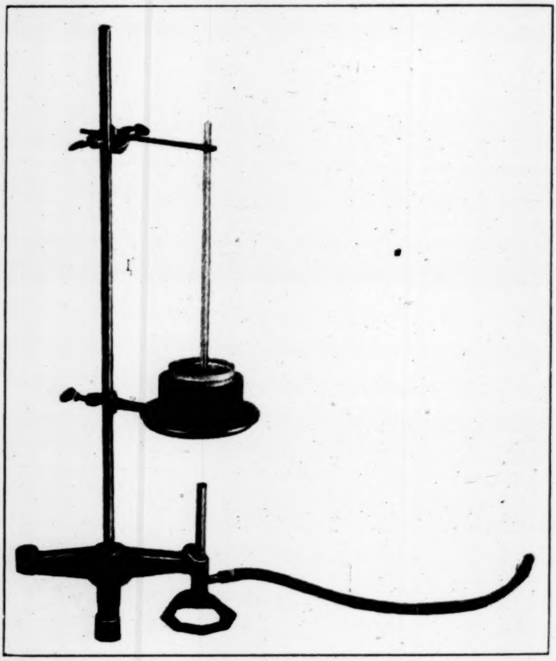

FIG. 2.—Assembly of Apparatus.

Heating. 8. The sample should be heated as rapidly as possible, to prevent foaming, to a temperature of 249° C. (480° F.) and during the evaporation, the temperature shall be maintained between 249° C. (480° F.) and 260° C. (500° F.). The sample shall be stirred with the thermometer from time to time to prevent local overheating and, to maintain a homogeneous sample, all cakes of hardened bitumen which form at the sides of the container shall be fluxed in the sample.

An experienced operator can judge approximately what percentage of residue he should obtain to secure the desired penetration.

When it is supposed that the residue will show the required penetration, the bitumen on the thermometer which may be readily scraped off shall be returned to the container, which then shall be removed from the air-bath, cooled and weighed. The penetration of the residue shall then be determined in accordance with the Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5) of the American Society for Testing Materials,[1] with the exception that the 6-oz. container specified in Section 3, in which the evaporation has been conducted, shall be used instead of the 3-oz. container specified in the Standard Method D 5.

9. It frequently is necessary to make several trials before a residue of the required penetration is obtained. If it is determined to be greater than that required, all water shall be removed from the container and the surface of the sample, and the heating and determination of penetration may be repeated as before. Ordinarily a residue shall be considered as satisfactorily obtained when its penetration is within 15 of that desired, and its percentage by weight of the original sample shall be calculated. When it is necessary to determine more precisely the percentage of residue having the specified penetration, such a percentage shall be computed by interpolation between percentages of two residues, one having a penetration greater and one having a penetration lower than that specified. The percentage shall be reported as:

Percentage of residue of .... penetration (determined ....) stating, first, the specified penetration, and second, the penetration actually determined for the sample tested or calculated by interpolation.

PRECAUTIONS

Precautions

10. Certain types of road oil will readily form rings of hard asphalt at the side of the container. Great care should be taken that this material be completely fluxed in the sample before the penetration of the residue is determined.

ACCURACY

Accuracy.

11. Duplicate determinations should not differ by more than 1.0 per cent with the same operator nor more than 2.5 per cent between different laboratories.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 971.

TENTATIVE METHODS OF SURVEYING AND SAMPLING SOILS FOR USE IN PLACE AS SUBGRADES FOR HIGHWAYS[1]

A.S.T.M. Designation: D 420 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Purpose of Subgrade Survey

1. The purpose of the subgrade survey is to furnish the engineer with significant information on the following subjects:

(*a*) The final location of the road both vertically and horizontally.

(*b*) The selection of suitable fill material.

(*c*) The design of the roadway section.

(*d*) The design and location of ditches, culverts and drains.

(*e*) The need for subgrade treatment and the type of treatment required.

(*f*) The selection of the type of road surface and its design.

Scope of Subgrade Survey

2. The subgrade survey consists of three parts, as follows:

(*a*) The determination of the soil profile.

(*b*) The selection of samples for the determination of the physical properties of the soils included in the profile.

(*c*) The mapping of the profile in order to supply information important to road design.

Equipment for Subgrade Survey

3. The following equipment is required to make a subgrade survey:

(*a*) One 3-ft. soil auger and three 3-ft. extensions as illustrated in Fig. 1.

(*b*) Two small pipe wrenches.

(*c*) One light pick.

(*d*) One shovel.

(*e*) A supply of sample bags.

(*f*) A supply of tags for marking samples.

(*g*) A ball of twine.

(*h*) One engineer's level.

(*i*) One hand level.

(*j*) One 12-ft. level rod, three-section.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

(*k*) One 100-ft. metallic tape.

(*l*) One 12 by 15 in. strip of stiff cardboard.

(*m*) One roll of 20-in. cross-section paper, 10 divisions to the inch each way.

(*n*) Notebooks.

(*o*) A supply of survey stakes.

(*p*) One camera and supply of films.

(*q*) A supply of keel.

Soil Profile Determination

4. The soil profile shall be determined by examining the soil in its natural field condition. This work is best accomplished by examining excavations, road cuts, etc., but the method of using a soil auger is the most common. There is no definite rule to follow in making these examinations, except that the soil should be examined at intervals close enough to determine the soil type and by borings deep enough to penetrate the more or less non-uniform layers of soil or soil material.

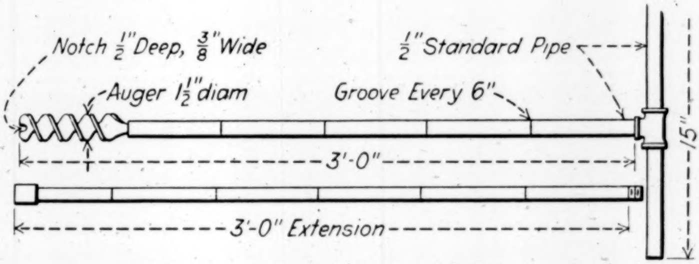

Notch $\frac{1}{2}$" Deep, $\frac{3}{8}$" Wide
$\frac{1}{2}$" Standard Pipe
Auger $1\frac{1}{2}$" diam
Groove Every 6"
15"
3'-0"
3'-0" Extension

FIG. 1.—Auger for Obtaining Soil Samples.

Examination of Soil Section

5. The examination of the soil section should proceed in a systematic way, paying particular attention to the properties described in the following Sections 6 to 12:

6. *Texture.*—The successive layers or horizons differing in texture, or in fineness or coarseness of the material, should be carefully examined. The examination should extend to a depth of at least 5 or 6 ft. The texture of each layer and its thickness should be described.

7. *Color.*—The successive layers which can be differentiated according to differences in color should be noted. Each layer should be described and its thickness given.

8. *Structure.*—The several layers that differ according to structure should be examined carefully, structure being defined as the kind and size of soil particle aggregation. Special note should be made of horizons with the following:

(*a*) Fine granular structure (granules about the size of bird shot or smaller).

(*b*) Coarse granular structure (granules ranging up to ½ in. or more in diameter and usually more angular or irregular in shape than the granules making up the fine granular structure).

(*c*) Layered or platey structure, in which the material splits into thin plates (not to be confused with stratification).

(*d*) Buckshot structure, in which the soil on drying breaks up into angular fragments (found to characterize heavy clays usually having a considerable percentage of lime).

(*e*) Single-grain structure in which the material is like flour or sand with no aggregation of particles.

9. *Consistency.*—A determination should be made of the successive layers or horizons differing in consistency (stickiness, friability, plasticity). A description of each should be given and its thickness noted.

10. *Compactness.*—The relative compactness of the several layers should be determined, as measured by the degree of resistance to the penetration of a pointed instrument.

11. *Cementation.*—It should be determined whether or not resistance to penetration is due in any horizon to cementation. If so, the probable cementing material (light colored or reddish, very strongly cemented or weakly cemented) should be ascertained.

12. *Chemical Composition.*—(*a*) While the determination of the chemical composition of the various parts of the soil section or profile can not be performed in the field by the usual field methods, there are certain features that may be determined in at least a qualitative way. Field examination can detect the presence of horizons with concentrations of organic matter or of salts of the alkalies and alkaline earths.

(*b*) The organic matter referred to in Paragraph (*a*) is that contained in the soil and not that lying on the soil. Of this there are two kinds to be looked for: namely,

(*1*) The organic matter in the surface soil is recognized by the dark color, and the approximate relative percentage present is indicated by the intensity of the dark color. The determination of the thickness of the dark-colored layer in the virgin soil is very important.

(*2*) In some soils, usually confined to regions with a cool, moist climate, there is present, at a depth ranging from 6 in. or less to somewhat more than a foot, a layer of brown or coffee-brown organic matter forming a film 6 or 8 in. in thickness.

(*c*) The salts of the alkalies and alkaline earths accumulate in the soil under favorable conditions. Since the work here contemplated is general and the soil characteristics dealt with are those of wide regional distribution, we may practically neglect all salts except the carbonate of lime. The more soluble salts constituting what is usually known as "alkali" are present in relatively small areas and may be neglected, or the soils in which they occur may be designated merely as alkali soils.

(*d*) Horizons of lime carbonate accumulation may be readily identified and should be looked for where the rainfall is less than 17 to 18 in. per year in cool to cold climates and 30 in. per year in hot or very warm climates. The unweathered material beneath the soil in any region, arid, subhumid, or humid may have a high percentage of lime carbonate, but such material should not be confused with the horizon of true lime carbonate accumulation.

(*e*) Sesquioxides accumulate in the soil under favorable conditions. Since accumulations of aluminum hydroxide are not readily identified by the usual field methods these may be left out of consideration. Accumulations of iron oxides are, however, important to consider.

(*f*) Iron oxides occur in two forms: The first form consists of accumulations of finely divided or colloidal iron oxide (hydroxide). The degree of concentration may be determined, within a rather wide range of error, by the intensity of the red color. The existence of red horizons in the soil profile should be noted and should be illustrated with samples, even though they be small. The second type consists of accumulations of iron oxide concretions or large masses, usually porous or slaglike. This statement does not refer to iron-stone slabs or ferruginous sandstone layers which may be found in many places in the parent geological formations. In hot countries the accumulations referred to here take the form of thick masses of porous slaglike iron oxide lying at depths ranging from somewhat less than 3 to more than 15 ft. They may consist of fragments scattered over the surface.

Selection of Samples

13. A 5-lb. sample of soil from each layer shall be obtained with pick and shovel from the exposed back slopes or from test pits dug at locations indicated by the borings. Each sample shall be placed in a canvas bag, tied securely, marked with proper identification and shipped to the laboratory. A sufficient number of samples shall be taken to determine the range in test results for what appears to be the same layer.

Mapping the Soil Profile

14. The detailed mapping of soil profiles shall be accomplished in the following manner:

(*a*) Vertical soil sections shall be examined at frequent intervals and classified into layers according to the method described above.

(*b*) The limits of the various layers shall be plotted as shown in Fig. 2 (*a*), alternate numbers being used to indicate the layers. Thus at test hole No. 1, the consecutive layers are numbered 1, 3, 5, etc., so as to allow the inclusion of any other layer which might enter the profile within the section mapped. At test hole No. 4, layer 2 is mapped between layers 1 and 3. This requires the examination of another test hole (No. 5), or perhaps several, between Nos. 3 and 4, to determine the horizontal limits of layer 2.

(*c*) The profile shall be completed by connecting the points marking the limits of the layers as shown in Fig. 2 (*b*).

SUBGRADE SURVEY TO OBTAIN INFORMATION REGARDING ROADS IN SERVICE

Subgrade Survey

15. The section for study having been selected, the survey shall be carried out as follows:

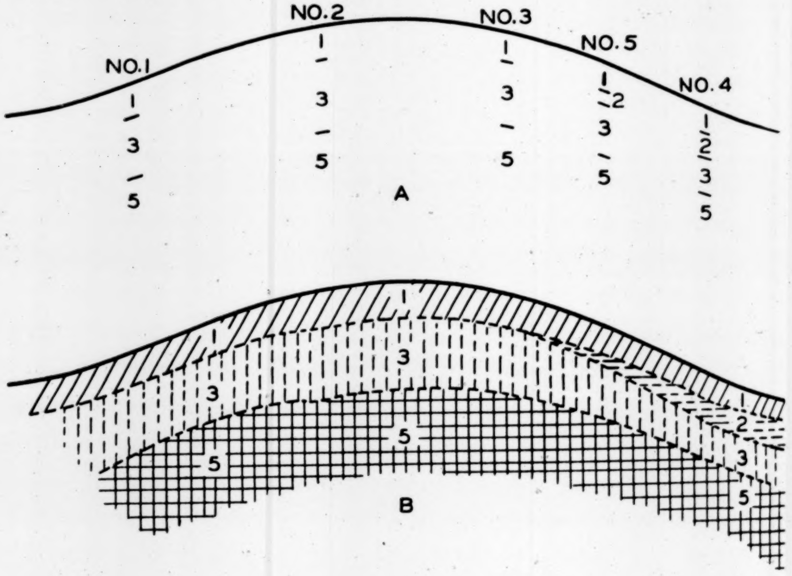


FIG. 2.—Example of Soil Profile Map.
Scales (appoximate due to reductions in reproduction):
Horizontal............¾ in. = 50 ft.
Vertical ....¾ in. = 5 ft.

(*a*) The section shall be staked out, the original construction stations being used if possible. Arbitrary stations will serve the purpose when it is not convenient to locate original stations.

(*b*) Cross sections shall be taken every 50 ft. along the center line or oftener if topography requires, and for a distance of 150 ft. on each side of the center line. Elevations shall be obtained with an engineer's level to the nearest 0.1 ft. The accuracy of an engineer's level is necessary for the construction of center-line and bank-line profiles, but a hand level is sufficiently accurate for the topography adjacent to the highway. An assumed elevation may be used as a bench mark.

(*c*) A plan of the roadway shall be drawn to a scale of 50 ft. to the inch, showing the type of pavement, type of failure, portion of roadway which is built over an older road, if any, and any special construction.

(*d*) Cross-section notes shall be plotted to the same scale as the plan of roadway and contours drawn in by interpolation.

(*e*) The bank-line profiles shall be drawn on the cross-section paper using a horizontal scale of 50 ft. to the inch and a vertical scale of 5 ft. to the inch. The center line profile and the grade line of the pre-existing road, if any, shall be projected upon the bank-line profiles.

Examining and Mapping Soil Profile

16. The soils shall be mapped and the profiles plotted according to the procedure outlined in Section 14. The desired information may be conveniently obtained and recorded in the following manner:

(*a*) Scrape down the back slopes so that the original undisturbed material is exposed and plot the limits of the various layers on the prepared profile sheets. Supplement this work by soil auger borings so that a profile is obtained to a depth of at least 3 to 5 ft. below the center-line grade. The depth will vary with the uniformity of the soil layers or soil material. Any variations in moisture content should be specially noted. Obtain the elevations of the limits of the different layers in the exposed back slopes by means of a hand level, the elevation of the center line being used as a bench mark.

(*b*) In a separate notebook describe each layer in detail according to the properties enumerated in Sections 6 to 12, inclusive, recording also the relative imperviousness or porosity of the individual layers.

(*c*) Examine the soil every 50 ft. or less, depending on the uniformity of the profile (see Section 14).

(*d*) On the plan of the roadway plot the limits of the various soil layers found directly under the surfacing material. When the roadway is cut through uniform layers of soil material, the limits are obtained by constructing cross-sections from the bank-line profiles. When the roadway is constructed of fill material or cut through a heterogeneous soil material, the limits are determined by soil auger borings in the shoulder.

Selection of Samples

17. Adequate samples shall be secured as described in Section 13.

Photographs of Road Surfaces

18. Photographs shall be taken illustrating the condition of the pavement, the shoulders, the back slopes, the ditches, and the appearance of the soil layers.

Analysis of Data

19. The data collected in the manner described above shall be analyzed, together with the laboratory test results, and information on the following subjects developed:

(*a*) The relation that exists between the pavement condition, the field characteristics of the soil, and the physical properties of the soil as determined in the laboratory.

(*b*) The possible reasons for failure.

(*c*) Possible curative measures for the case under examination.

(*d*) Preventive measures which may be applied in the future.

SUBGRADE SURVEY TO OBTAIN INFORMATION WITH RESPECT TO THE DESIGN OF A NEW ROAD

Study of Soil Information and Preliminary Survey

20. Before starting a subgrade survey of this kind the engineer should make a study of all the existing information on the soil types in that vicinity. Wherever soil maps prepared by the Bureau of Chemistry and Soils, U. S. Department of Agriculture, are available, they should be carefully studied, and the limits of the various soil types and their characteristics should be noted. It must be kept in mind that the detail to which such maps are carried is not particularly adapted to a subgrade survey. Nevertheless, they give a clear idea of the variations which will be encountered. Where this information is not available, a reconnaisance survey should be made of the soil materials on existing highways which parallel the new highway, noting the changes in soil as shown in exposed cuts. The notes should include a complete description of each soil type. The value of the information obtained from this rough survey lies in the fact that similar soil conditions may be expected to accompany similar topographic features.

Subgrade Survey

21. After this information has been digested the survey shall proceed in accordance with the following Sections 22 to 26. The profile of the ground line and the proposed grade line shall be constructed on the same type of sheet as was specified for subgrade surveys of existing roads in service as described in Sections 15 and 16.

Mapping and Sampling Soil Profile

22. Borings shall be made with a soil auger at frequent intervals and each soil type classified into layers, as described in Sections 4 to 15.

(*a*) *Spacing of Borings.*—The spacing of borings should vary with the uniformity of the profile and the topography. A convenient interval, such as the even stations, may be assumed at the beginning. This interval may be varied under the following conditions: (*1*) If the profile is uniform, the interval may be increased; (*2*) When the character of the profile changes, intermediate borings should be made until it is clear that all variations have been mapped; (*3*) Where topography is rolling and grade changes rapidly from cut to fill, borings are necessary only in the cuts; (*4*) Where

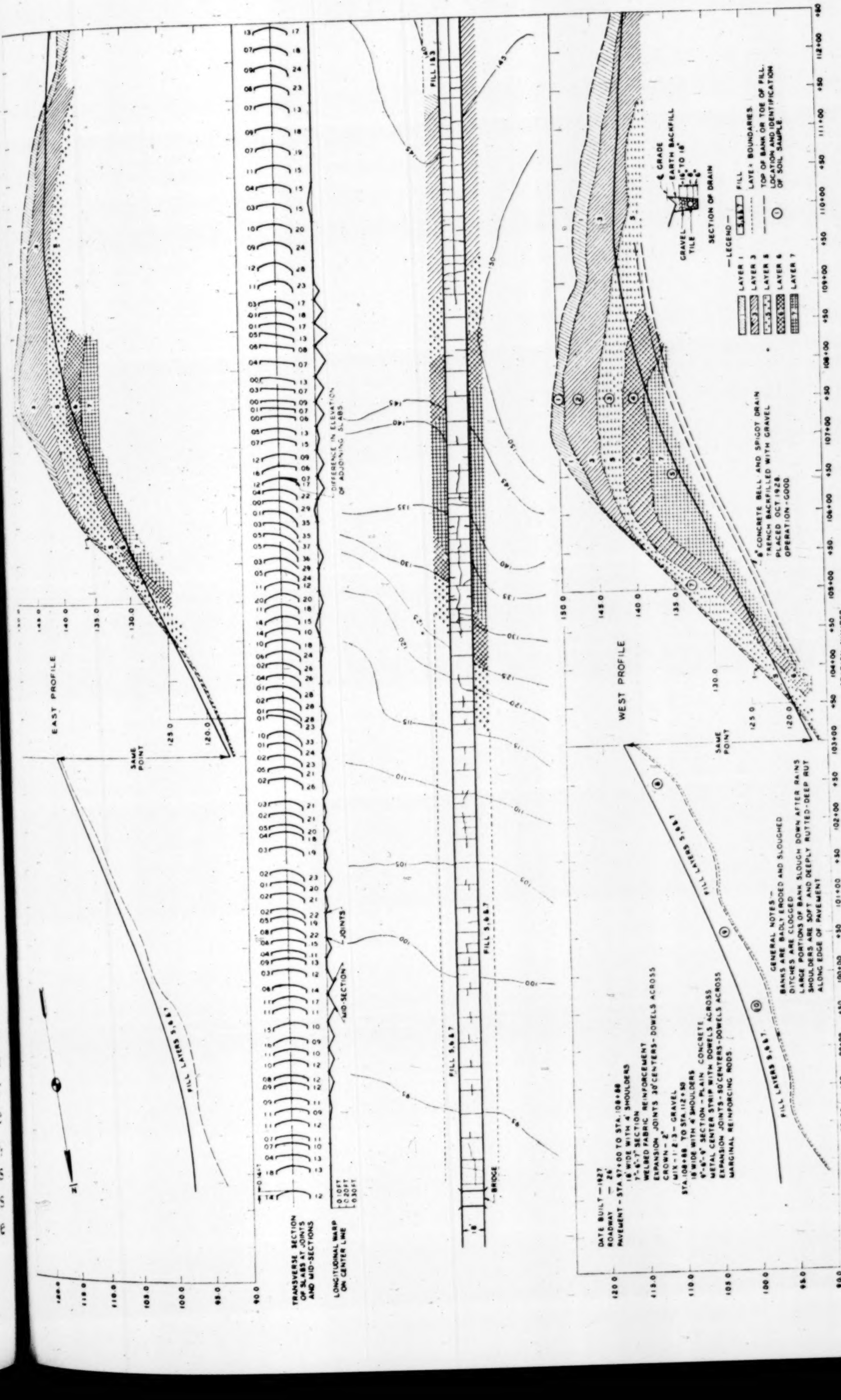
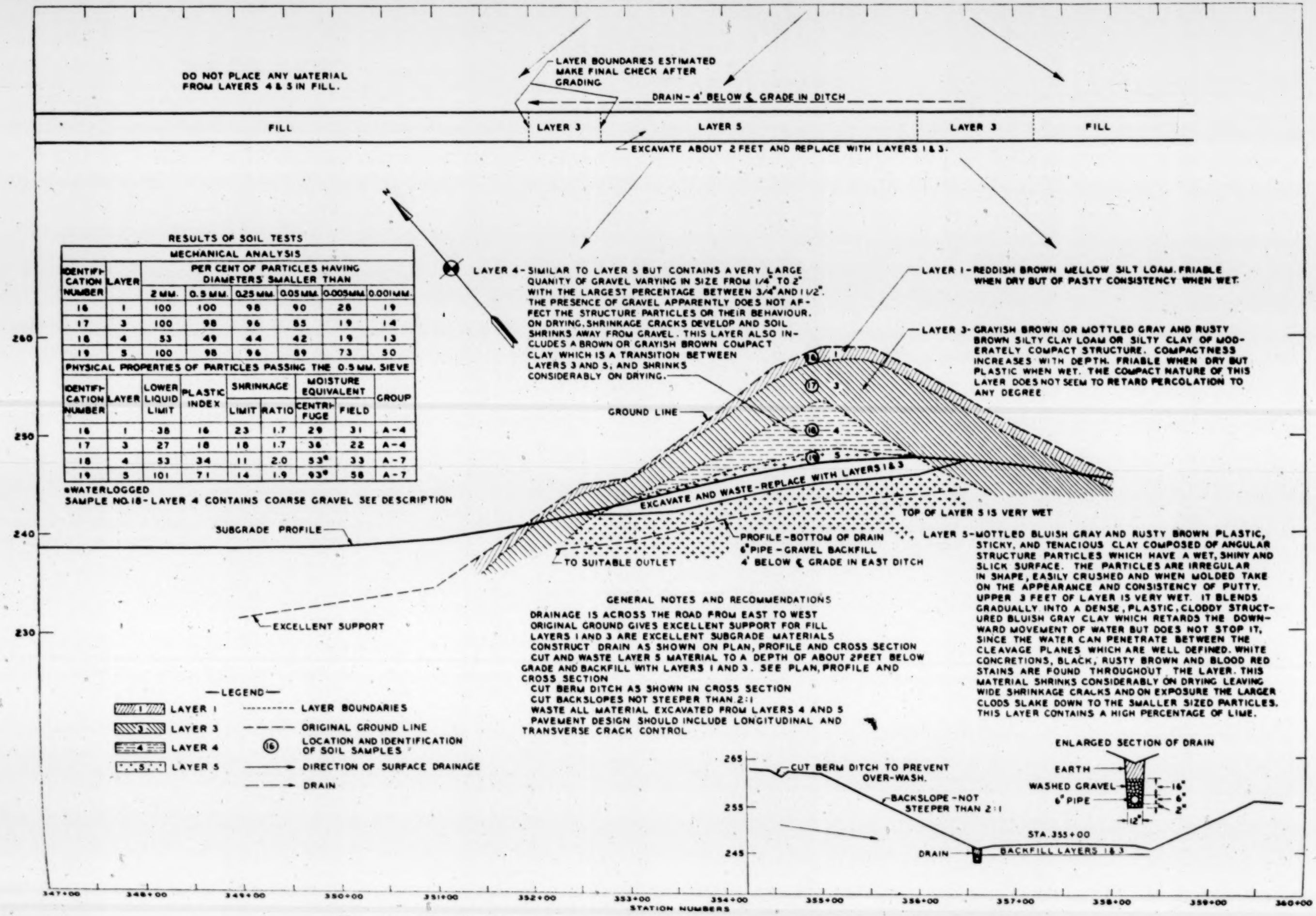

EAST PROFILE
SAME POINT
FILL LAYERS 5, 6 & 7
N
TRANSVERSE SECTION OF SLABS AT JOINTS AND MID-SECTIONS
LONGITUDINAL WARP ON CENTER LINE
0.10 FT
0.20 FT
0.30 FT
DIFFERENCE IN ELEVATION OF ADJOINING SLABS
JOINTS
MID-SECTION
FILL 1 & 3
FILL 5, 6 & 7
BRIDGE
WEST PROFILE
STATION NUMBER
DATE BUILT — 1927
ROADWAY — 26'
PAVEMENT – STA. 97+00 TO STA. 108+88
18' WIDE WITH 4' SHOULDERS
7"-6"-7" SECTION
WELDED FABRIC REINFORCEMENT
EXPANSION JOINTS 30' CENTERS – DOWELS ACROSS
CROWN – 2"
MIX – 1 : 2 : 3 – GRAVEL
STA. 108+88 TO STA. 112+50
18' WIDE WITH 4' SHOULDERS
9"-6"-9" SECTION – PLAIN CONCRETE
METAL CENTER STRIP WITH DOWELS ACROSS
EXPANSION JOINTS – 50' CENTERS – DOWELS ACROSS
MARGINAL REINFORCING RODS
GENERAL NOTES –
BANKS ARE BADLY ERODED AND SLOUGHED
DITCHES ARE CLOGGED
LARGE PORTIONS OF BANK SLOUGH DOWN AFTER RAINS
SHOULDERS ARE SOFT AND DEEPLY RUTTED – DEEP RUT ALONG EDGE OF PAVEMENT
6" CONCRETE BELL AND SPIGOT DRAIN
TRENCH BACKFILLED WITH GRAVEL
PLACED OCT. 1928
OPERATION – GOOD
℄ GRADE
EARTH BACKFILL
16" TO 18"
GRAVEL
TILE
SECTION OF DRAIN
— LEGEND —
LAYER 1
LAYER 3
LAYER 5
LAYER 6
LAYER 7
FILL
LAYER BOUNDARIES
TOP OF BANK OR TOE OF FILL
LOCATION AND IDENTIFICATION OF SOIL SAMPLE

FIG. 3.—Typical Subgrade Survey Sheet for a Road in Service.


DO NOT PLACE ANY MATERIAL FROM LAYERS 4 & 5 IN FILL.
LAYER BOUNDARIES ESTIMATED MAKE FINAL CHECK AFTER GRADING.
DRAIN - 4' BELOW ℄ GRADE IN DITCH
FILL
LAYER 3
LAYER 5
LAYER 3
FILL
EXCAVATE ABOUT 2 FEET AND REPLACE WITH LAYERS 1 & 3.
N
260
250
240
230
GROUND LINE
SUBGRADE PROFILE
EXCAVATE AND WASTE-REPLACE WITH LAYERS 1 & 3
TOP OF LAYER 5 IS VERY WET
PROFILE-BOTTOM OF DRAIN 6" PIPE - GRAVEL BACKFILL 4' BELOW ℄ GRADE IN EAST DITCH
TO SUITABLE OUTLET
EXCELLENT SUPPORT
16
17
18
19
1
3
4
5
—LEGEND—
LAYER 1
LAYER 3
LAYER 4
LAYER 5
LAYER BOUNDARIES
ORIGINAL GROUND LINE
LOCATION AND IDENTIFICATION OF SOIL SAMPLES
DIRECTION OF SURFACE DRAINAGE
DRAIN
ENLARGED SECTION OF DRAIN
EARTH
WASHED GRAVEL
6" PIPE
16"
6"
2"
12"
265
255
245
CUT BERM DITCH TO PREVENT OVER-WASH.
BACKSLOPE - NOT STEEPER THAN 2:1
STA. 355+00
DRAIN
BACKFILL LAYERS 1 & 3
347+00
348+00
349+00
350+00
351+00
352+00
353+00
354+00
355+00
356+00
357+00
358+00
359+00
360+00
STATION NUMBERS

RESULTS OF SOIL TESTS

MECHANICAL ANALYSIS							
IDENTIFICATION NUMBER	LAYER	PER CENT OF PARTICLES HAVING DIAMETERS SMALLER THAN					
		2 MM.	0.5 MM.	0.25 MM.	0.05 MM.	0.005 MM.	0.001 MM.
16	1	100	100	98	90	28	19
17	3	100	98	96	85	19	14
18	4	53	49	44	42	19	13
19	5	100	98	96	89	73	50

PHYSICAL PROPERTIES OF PARTICLES PASSING THE 0.5 MM. SIEVE								
IDENTIFICATION NUMBER	LAYER	LOWER LIQUID LIMIT	PLASTIC INDEX	SHRINKAGE		MOISTURE EQUIVALENT		GROUP
				LIMIT	RATIO	CENTRIFUGE	FIELD	
16	1	38	16	23	1.7	29	31	A-4
17	3	27	18	18	1.7	36	22	A-4
18	4	53	34	11	2.0	53*	33	A-7
19	5	101	71	14	1.9	93*	58	A-7

*WATERLOGGED
SAMPLE NO. 18 - LAYER 4 CONTAINS COARSE GRAVEL SEE DESCRIPTION

LAYER 1 - REDDISH BROWN MELLOW SILT LOAM. FRIABLE WHEN DRY BUT OF PASTY CONSISTENCY WHEN WET.

LAYER 3 - GRAYISH BROWN OR MOTTLED GRAY AND RUSTY BROWN SILTY CLAY LOAM OR SILTY CLAY OF MODERATELY COMPACT STRUCTURE. COMPACTNESS INCREASES WITH DEPTH. FRIABLE WHEN DRY BUT PLASTIC WHEN WET. THE COMPACT NATURE OF THIS LAYER DOES NOT SEEM TO RETARD PERCOLATION TO ANY DEGREE

LAYER 4 - SIMILAR TO LAYER 5 BUT CONTAINS A VERY LARGE QUANITY OF GRAVEL VARYING IN SIZE FROM 1/4" TO 2" WITH THE LARGEST PERCENTAGE BETWEEN 3/4" AND 1 1/2". THE PRESENCE OF GRAVEL APPARENTLY DOES NOT AFFECT THE STRUCTURE PARTICLES OR THEIR BEHAVIOUR. ON DRYING, SHRINKAGE CRACKS DEVELOP AND SOIL SHRINKS AWAY FROM GRAVEL. THIS LAYER ALSO INCLUDES A BROWN OR GRAYISH BROWN COMPACT CLAY WHICH IS A TRANSITION BETWEEN LAYERS 3 AND 5, AND SHRINKS CONSIDERABLY ON DRYING.

LAYER 5 - MOTTLED BLUISH GRAY AND RUSTY BROWN PLASTIC, STICKY, AND TENACIOUS CLAY COMPOSED OF ANGULAR STRUCTURE PARTICLES WHICH HAVE A WET, SHINY AND SLICK SURFACE. THE PARTICLES ARE IRREGULAR IN SHAPE, EASILY CRUSHED AND WHEN MOLDED TAKE ON THE APPEARANCE AND CONSISTENCY OF PUTTY. UPPER 3 FEET OF LAYER IS VERY WET. IT BLENDS GRADUALLY INTO A DENSE, PLASTIC, CLODDY STRUCTURED BLUISH GRAY CLAY WHICH RETARDS THE DOWNWARD MOVEMENT OF WATER BUT DOES NOT STOP IT, SINCE THE WATER CAN PENETRATE BETWEEN THE CLEAVAGE PLANES WHICH ARE WELL DEFINED. WHITE CONCRETIONS, BLACK, RUSTY BROWN AND BLOOD RED STAINS ARE FOUND THROUGHOUT THE LAYER. THIS MATERIAL SHRINKS CONSIDERABLY ON DRYING LEAVING WIDE SHRINKAGE CRALKS AND ON EXPOSURE THE LARGER CLODS SLAKE DOWN TO THE SMALLER SIZED PARTICLES. THIS LAYER CONTAINS A HIGH PERCENTAGE OF LIME.

GENERAL NOTES AND RECOMMENDATIONS

DRAINAGE IS ACROSS THE ROAD FROM EAST TO WEST
ORIGINAL GROUND GIVES EXCELLENT SUPPORT FOR FILL
LAYERS 1 AND 3 ARE EXCELLENT SUBGRADE MATERIALS
CONSTRUCT DRAIN AS SHOWN ON PLAN, PROFILE AND CROSS SECTION
CUT AND WASTE LAYER 5 MATERIAL TO A DEPTH OF ABOUT 2 FEET BELOW GRADE AND BACKFILL WITH LAYERS 1 AND 3. SEE PLAN, PROFILE AND CROSS SECTION
CUT BERM DITCH AS SHOWN IN CROSS SECTION
CUT BACKSLOPES NOT STEEPER THAN 2:1
WASTE ALL MATERIAL EXCAVATED FROM LAYERS 4 AND 5
PAVEMENT DESIGN SHOULD INCLUDE LONGITUDINAL AND TRANSVERSE CRACK CONTROL

FIG. 4.—Typical Subgrade Survey Sheet for the Design of a New Road.

the original ground line or old road grade is to be covered with fill material, no examination is necessary except to determine the character of the support. If the fill material is to be obtained from borrow ditches along the road, the soil should be examined to the entire depth of the borrow.

(*b*) *Depth of Borings.*—The borings should generally be carried to a depth of at least 3 ft. below the grade line. The depth may vary in accordance with the following stipulations: (*1*) When the road lies within the uniform layers of the soil profile, the boring should extend down to the first layer below the ditch line which would block percolation, or through a pervious layer which would carry water; (*2*) When fill material is to be borrowed from ditches alongside the road, the boring should extend at least to the estimated depth of borrow; (*3*) In the study of frost action the borings should extend to the mean depth of frost in those soil materials showing a high affinity for frost accumulation and in localities where high water tables prevail.

(*c*) When the located line is over an old road, the soils may be mapped by examining the exposed cuts. This work should be supplemented by borings.

(*d*) A notation shall be made of the direction of surface drainage with respect to the proposed roadway.

Mapping Soil Profile

23. The data obtained from the borings shall be plotted on the prepared profile sheet. On this sheet shall also be indicated the limits of the several types and layers, the relative moisture content at various depths, and the location of culverts and drains.

Examination of Soil Section

24. In a separate notebook the field characteristics of each layer shall be described according to the properties enumerated in Sections 6 to 12, inclusive. The relative imperviousness or porosity of each layer shall also be indicated.

Selection of Samples

25. Adequate samples shall be obtained as described in Section 13.

Analysis of Data

26. (*a*) Recommendations regarding the design of the road surface shall be made on the basis of the known behavior of pavements for which the conditions of soil, climate and topography are similar.

(*b*) After the road is graded a final check shall be made on the soil as exposed by grading operations.

(*c*) Typical subgrade survey sheets are shown in Figs. 3 and 4.

TENTATIVE METHOD OF PREPARING SOIL SAMPLES AS RECEIVED FROM THE FIELD FOR MECHANICAL ANALYSIS AND THE DETERMINATION OF THE SUBGRADE SOIL CONSTANTS[1]

A.S.T.M. Designation: D 421 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method covers the preparation of soil samples as received from the field for mechanical analysis and the determination of the subgrade soil constants.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance sensitive to 0.1 g.

(*b*) *Mortar.*—A mortar and rubber-covered pestle suitable for breaking up the aggregations of soil particles.

(*c*) *Sieves.*—A series of sieves, of square-mesh wire cloth, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3] The sizes required are shown in Table I.

(*d*) *Sampler.*—A riffle sampler or sample splitter, for quartering the samples.

TABLE I.—REQUIREMENTS FOR SIEVE OPENINGS AND WIRE DIAMETERS WITH PERMISSIBLE VARIATIONS.

Mesh Designation, U. S. Standard Sieve Series	Sieve Opening		Wire Diameter		Tolerances, per cent			
					Average Opening	Wire Diameter		Maximum Opening
	mm.	in.	mm.	in.		Under	Over	
No. 4	4.76	0.1870	1.27	0.050	±3	15	30	10
No. 10	2.00	0.0787	0.76	0.0299	±3	15	30	10
No. 40	0.42	0.0165	0.25	0.0098	±5	15	30	25
No 200	0.074	0.0029	0.053	0.0021	±8	15	35	60

Sampling

3. The soil sample as received from the field shall be dried thoroughly in the air. A representative test sample of the amount required to perform the desired tests shall then be selected by the method of quartering or by

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

the use of a sampler. The amounts of material required to perform the individual tests are as follows:

(*a*) *Mechanical Analysis.*—For the mechanical analysis, material passing a No. 10 sieve is required in amounts equal to 115 g. of sandy soils and 65 g. of either silt or clay soils.

(*b*) *Physical Tests.*—For the physical tests, material passing the No. 40 sieve is required in total amount equal to 200 g., allocated as follows:

	GRAMS
Liquid limit	30
Plastic limit	15
Centrifuge moisture equivalent	10
Field moisture equivalent	50
Volumetric shrinkage	30
Check tests	65

(*c*) *Tests of Binder Materials.*—Physical tests of binder material shall be performed only when it is desired to investigate the properties of the active constituents in sand-clay and gravel road-surfacing materials. In this case 100 g. of the material passing the No. 200 sieve are required and the tests shall be performed in the following order:

Field moisture equivalent
Plastic limit
Liquid limit
Volumetric shrinkage
Centrifuge moisture equivalent.

The material remaining after the conclusion of each test shall be used in the next test, except that the test for the centrifuge moisture equivalent shall be made with material not used in previous tests.

Preparation of Test Sample

4. (*a*) That portion of the air-dried sample selected for purpose of tests shall be weighed and the weight recorded as the weight of the total test sample uncorrected for hygroscopic moisture. The test sample shall be separated by sieving with a No. 10 sieve. That fraction retained on the No. 10 sieve shall be ground in a mortar with a rubber-covered pestle until the aggregations of soil particles are broken up into the separate grains. The ground soil shall then be separated into two fractions by sieving with a No. 10 sieve.

(*b*) That fraction retained after the second sieving shall be washed free of all fine material, dried, and weighed. This weight shall be recorded as the weight of coarse material. The coarse material after being washed and dried shall be sieved on the No. 4 sieve and the weight retained on the No. 4 sieve recorded.

Test Sample for Mechanical Analysis

5. The fractions passing the No. 10 sieve in both sieving operations shall be thoroughly mixed together, and by the method of quartering or the

use of a sampler a portion weighing approximately 115 g. for sandy soils and approximately 65 g. for silt and clay soils shall be selected for mechanical analysis.

Test Sample for Subgrade Soil Constants

6. The remaining portion of the material passing the No. 10 sieve shall then be separated into two parts by means of a No. 40 sieve. The fraction retained on the No. 40 sieve shall be discarded. The fraction passing the No. 40 sieve shall be used for the determination of the subgrade soil constants.

TENTATIVE METHOD OF MECHANICAL ANALYSIS OF SOILS[1]

A.S.T.M. Designation: D 422 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.[2]

Scope

1. This method covers the quantitative determination of the distribution of particle sizes in soils.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Balance.*—An analytical balance sensitive to 0.001 g.

(*b*) *Stirring Apparatus.*—A special stirring apparatus (Fig. 1) with replaceable stirring paddle (Fig. 2) and specially designed dispersion cup of either of the designs shown in Fig. 3.

(*c*) *Hydrometer.*—A hydrometer graduated in grams of soil per liter of suspension (Fig. 4, *A*) *or* a hydrometer with special shape bulb, graduated in specific gravity, having a range of 0.995 to 1.050 specific gravity and reading 1.000 at 67 F. (19.4 C.) (Fig. 4, *B*).

(*d*) *Glass Graduate.*—A glass graduate 18 in. in height and 2½ in. in diameter and graduated for a volume of 1000 cc.

(*e*) *Thermometer.*—A Fahrenheit thermometer accurate to 1 F. (0.5 C.).

(*f*) *Sieves.*—A series of sieves, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3] The sieves required are Nos. 20, 40, 60, 140, and 200.

(*g*) *Water Bath.*—A water bath for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory device is an insulated zinc tank which maintains the temperature of the suspension at faucet-water temperature. Such a device is illustrated in Fig. 5.

(*h*) *Beaker.*—A tall form beaker of 400-ml. capacity.

Sample

3. A sample of soil shall be selected by the method of quartering or by the use of a sampler from the material passing the No. 10 sieve. The weight of each sample shall be approximately 115 g. for sandy soils and 65 g. for silt and clay soils and shall be obtained in accordance with the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 35 T) of the American Society for Testing Materials.[1]

HYGROSCOPIC MOISTURE

Hygroscopic Moisture

4. A 15-g. portion of the sample selected for mechanical analysis shall be used for the determination of the hygroscopic moisture. This portion of the sample shall be weighed, dried to constant weight in an oven at 110 C., weighed, and the results recorded.

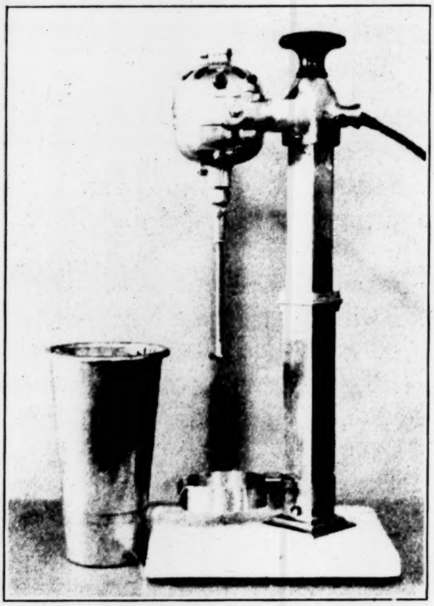

FIG. 1.—Stirring Apparatus.

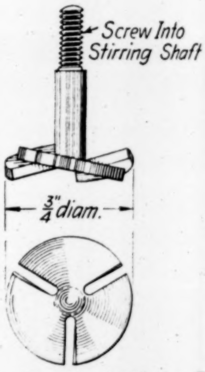

FIG. 2.—Detail of Stirring Paddle.

HYDROMETER TEST

Dispersion of Soil Sample

5. The remainder of the sample selected for mechanical analysis shall be weighed and dispersed by one of the two methods *A* or *B* described below. The method to be used depends on the plasticity index of the soil determined in accordance with the Tentative Method of Test for Plastic Limit and Plasticity Index of Soils (A.S.T.M. Designation: D 424 – 35 T) of the American Society for Testing Materials.[2]

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[1] See p. 950.
[2] See p. 970.

Method A: For Soils Having a Plasticity Index Less Than 20.—The soil shall be placed in a tall-form beaker, and 200 ml. or more of distilled water added slowly and with constant stirring until the soil is thoroughly wetted. The mixture shall be allowed to stand for a period of at least 18 hr. It shall then be washed into the special dispersion cup and distilled water added until the cup is within 2 in. of being filled. A deflocculating agent, 20 ml. of a solution of sodium silicate crystals ($Na_2SiO_3 \cdot 9\ H_2O$) shall be added. The density of this solution shall be that indicated by one of the following hydrometer readings: hydrometer *A*, 36.5 at 67 F. (19.4 C.); hydrometer *B*, 1.023 at 67 F. (19.4 C.); Baumé hydrometer, 3 deg. at 76 F. (24.4 C.). The contents of the cup shall be mixed by the special stirring apparatus (Note) for a period of 1 min.

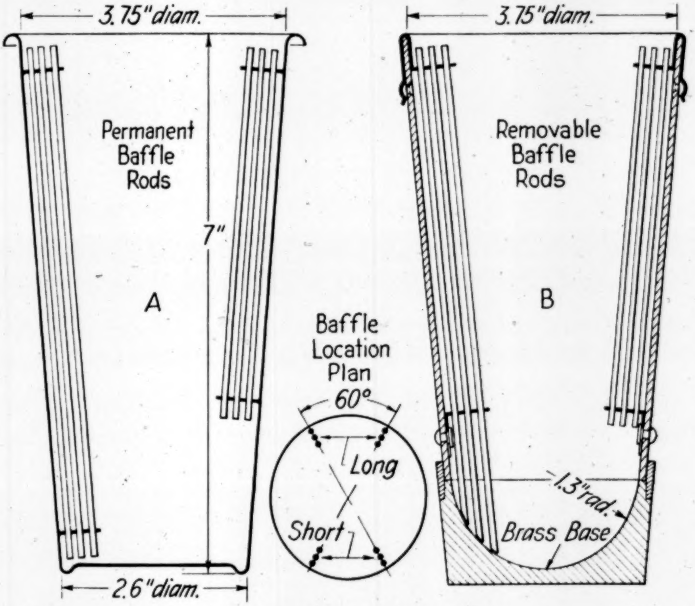

FIG. 3.—Dispersion Cups.

Method B: For Soils Having a Plasticity Index Greater Than 20.—The soil shall be placed in a tall-form beaker, and 100 ml. of 6 per cent hydrogen peroxide added slowly and with constant stirring until the soil is thoroughly wetted. The beaker shall then be covered with a watch glass and placed in an oven at a temperature of 110 C. for 1 hr. The purpose of the peroxide is to assist in the dispersion rather than to remove the organic matter. The beaker shall then be removed from the oven, 100 ml. of distilled water added, and the mixture allowed to stand for at least 18 hr. The mixture shall then be washed into the special dispersion cup, and dispersed (Note) in the same manner and for the same length of time as in method *A*.

NOTE.—It is important in all cases to see that the paddle on the dispersion machine is replaced as soon as it shows signs of wear.

Hydrometer Test

6. (*a*) After dispersion, the mixture shall be transferred to the glass graduate, and distilled water having the same temperature as the constant temperature bath added until the mixture attains a volume of 1000 ml. The graduate containing the soil suspension shall then be placed in the constant temperature bath. The suspension shall be stirred frequently with a glass rod to prevent settlement of particles in suspension. When the soil suspension attains the temperature of the bath the graduate shall be removed and its contents thoroughly shaken for 1 min., the palm of the hand being used as a stopper over the mouth of the graduate.

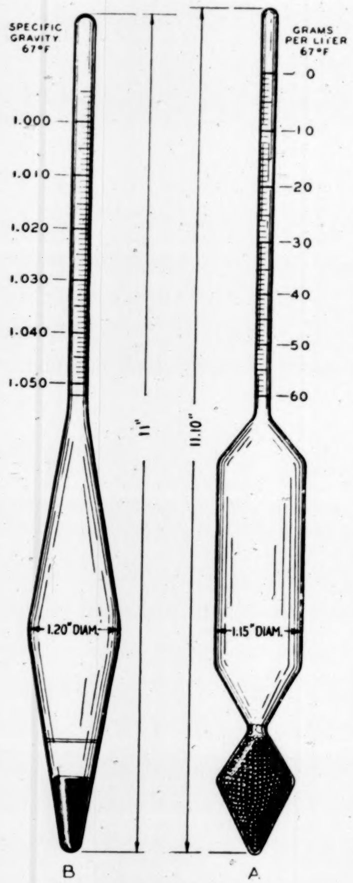
SPECIFIC GRAVITY 67°F
1.000
1.010
1.020
1.030
1.040
1.050
1.20" DIAM.
11"
11.10"
GRAMS PER LITER 67°F
0
10
20
30
40
50
60
1.15" DIAM.
B
A

FIG. 4.—Hydrometers.

(*b*) At the conclusion of this shaking the time shall be recorded, the graduate placed in the bath, and readings taken with the hydrometer at the end of both 1 and 2 min. The hydrometer shall be read at the top of the meniscus formed by the suspension around its stem. If hydrometer *A* is used, it shall be read to the nearest ½ g. per liter. Hydrometer ***B*** shall be read to the nearest 0.0005 specific gravity. Subsequent readings shall be taken at intervals of 5, 15, 30, 60, 250 and 1440 min. after the beginning of sedimentation. Readings on the thermometer placed in the constant temperature bath shall be made coincidentally with the hydrometer readings and recorded.

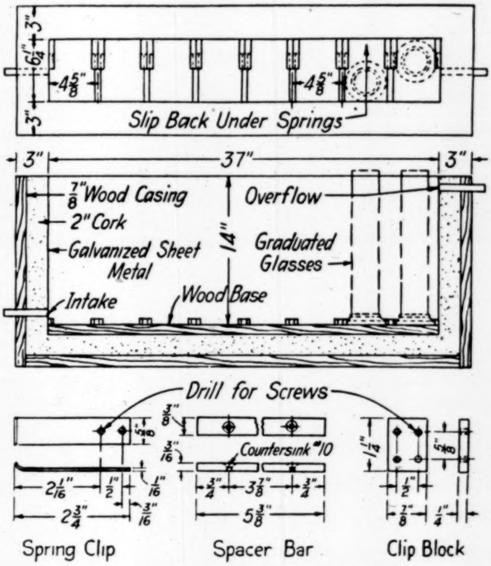
3"
6¼"
3"
4⅝"
4⅝"
Slip Back Under Springs
3"
37"
3"
⅞" Wood Casing
2" Cork
Galvanized Sheet Metal
Intake
Wood Base
14"
Overflow
Graduated Glasses
Drill for Screws
Countersink #10
2 1/16"
½"
1/16"
2¾"
3/16"
⅜"
⅝"
3/16"
¾"
3⅞"
¾"
5⅜"
1¼"
½"
⅞"
¼"
⅝"
Spring Clip
Spacer Bar
Clip Block

FIG. 5.—Insulated Water Bath.

(*c*) After each reading except the 1-min. reading, the hydrometer shall be very carefully removed from the soil suspension in such a manner as to cause no disturbance in the suspension, wiped clean, and laid aside. About 15 or 20 sec. before the time for a reading it shall again be slowly and carefully placed in the soil suspension. The reading shall not be taken until the hydrometer has come to rest.

SIEVE ANALYSIS

Sieve Analysis

7. At the conclusion of the final reading the suspension shall be washed on a No. 200 sieve. That fraction retained on the No. 200 sieve shall be dried and then analyzed in a nest of sieves consisting of one each of the following: Nos. 20, 40, 60, 140 and 200.

CALCULATIONS

Hygroscopic Moisture

8. The hygroscopic moisture shall be expressed as a percentage of the weight of the oven-dried soil and shall be determined by the following formula:

$$\text{Hygroscopic moisture} = \frac{\text{weight of air-dried soil} - \text{weight of oven-dried soil}}{\text{weight of oven-dried soil}} \times 100$$

To correct the weight of the air-dried sample for hygroscopic moisture the given value shall be multiplied by the expression:

$$\frac{100}{100 + \text{percentage of hygroscopic moisture}}$$

Coarse Material

9. (*a*) The percentage of coarse material shall be obtained from the data recorded during the preparation of the sample in accordance with the Tentative Method of Preparing Soil Sample as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 35 T) of the American Society for Testing Materials.[1]

(*b*) The coarse material shall be determined as follows: From the weight of the air-dried total test sample subtract the weight of the oven-dried fraction retained on the No. 10 sieve. The difference is assumed to equal the weight of the air-dried fraction passing the No. 10 sieve. According to this assumption, no hygroscopic moisture is contained in the air-dried particles retained on the No. 10 sieve, when as a matter of fact a small percentage of moisture may be present in this fraction. This amount of moisture, compared with that held in the pores of the fraction passing the No. 10 sieve, is relatively small. Therefore, any error produced by the assumption as stated may be considered negligible in amount. The weight of the fraction passing the No. 10 sieve shall be corrected for hygroscopic moisture as indicated in Section 8. To this value add the weight of the oven-dried fraction retained on the No. 10 sieve to obtain the weight of the total test sample corrected for hygroscopic moisture. The fractions retained on both the No. 4 and the No. 10 sieve shall be expressed as percentages of the corrected weight of the total test sample.

Example.—The following illustration is an example of the data used in calculating the hygroscopic moisture and percentage of coarse material:

Hygroscopic Moisture

Weight of air-dried soil, g	15.00
Weight of oven-dried soil, g	14.63
Hygroscopic moisture, percentage of weight of oven-dried soil	2.53
Hygroscopic moisture correction factor	0.975

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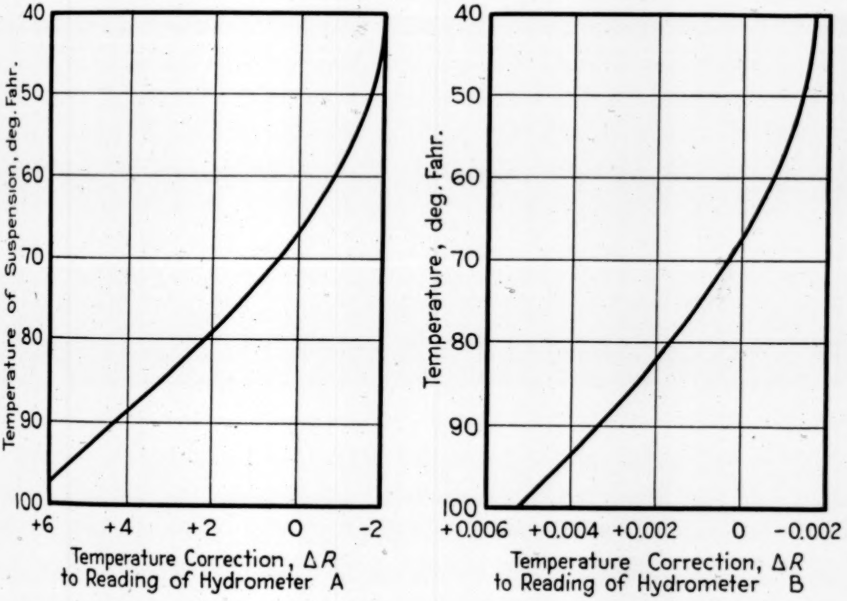
[1] See p. 950.

Coarse Material

Weight of total test sample, air-dried, g	318.3
Weight of washed and oven-dried fraction retained on No. 10 sieve, g	56.2
Weight of fraction passing No. 10 sieve, air-dried, g	262.1
Weight of fraction passing No. 10 sieve corrected for hygroscopic moisture, g	255.5
Weight of total test sample corrected for hygroscopic moisture, g	311.7
Weight of fraction retained on No. 4 sieve, oven-dried, g	40.6
Fraction retained on No. 4 sieve, percentage of corrected weight of total test sample	13.0
Fraction retained on No. 10 sieve, percentage of corrected weight of total test sample	18.0

Percentage of Soil in Suspension

10. (*a*) For temperatures of the constant temperature bath other than that at which the hydrometers were calibrated, the readings of hydrometer *A* shall be corrected by adding temperature-correction factors such as are shown graphically as Δ R in Fig. 6 (*a*). A temperature-correction curve of this type should be determined experimentally for each hydrometer of type *A* used.



(a) (b)

FIG. 6.—Temperature-Correction Curves for Hydrometer Readings.

(*b*) Readings of hydrometer *B* shall be corrected by adding temperature-correction factors shown as Δ R in Fig. 6 (*b*). The temperature-correction curve for hydrometer *B* is determined by plotting the differences between the density of water at the various temperatures and that at 67 F. (19.4 C.) against temperatures from 40 to 100 F. (4.4 to 37.8 C.).

(*c*) The percentage of the dispersed soil in suspension represented by different corrected hydrometer readings depends upon both the amount and the specific gravity of the soil dispersed. The percentage of dispersed soil remaining in suspension may be obtained from the following formulas:

$$\text{For hydrometer } A\text{: } P = \frac{Ra}{W} \times 100$$

$$\text{For hydrometer } B\text{: } P = \frac{1606\,(R-1)a}{W} \times 100$$

where P = the percentage of originally dispersed soil remaining in suspension
R = the corrected hydrometer reading
W = the weight of soil originally dispersed, in grams
a = constant depending on the density of the suspension

For hydrometer A, the value of a, for a specific gravity G and a water density at 67 F. (19.4 C.) of 0.9984, may be obtained from the following formula:

$$a = \frac{2.6500 - 0.9984}{2.6500} \times \frac{G}{G - 0.9984}$$

For hydrometer B, the value of a for an assumed density of 1.0000 at 67 F. (19.4 C.) may be obtained from the following formula:

$$a = \frac{2.6500 - 1.0000}{2.6500} \times \frac{G}{G - 1.0000}$$

The values of a given by the two equations for different values of the specific gravity of soil G, are the same to two decimal places, and are as follows:

SPECIFIC GRAVITY, G	CONSTANT, a
2.95	0.94
2.85	0.96
2.75	0.98
2.65	1.00
2.55	1.02
2.45	1.05
2.35	1.08

It is sufficiently accurate for ordinary tests to select the constant for the specific gravity nearest to that of the particular soil tested.

Example.—Assume that the weight of dispersed soil corrected for hygroscopic moisture is 48.5 g., the uncorrected reading of hydrometer A is 34, the specific gravity 2.41, and the temperature of suspension 70 F. (21 C.). The temperature correction is then +0.4 (Fig. 6 (*a*)) and the corrected reading, R, is $34 + 0.4 = 34.4$. The specific gravity correction, a, is 1.05.

$$\text{Then } P = \frac{34.4 \times 1.05}{48.5} \times 100 = 74.5.$$

(*d*) The percentage of the total test sample, including the fraction retained on the No. 10 sieve, shall be obtained by multiplying the percentage of originally dispersed soil remaining in suspension by the expression:

$$\frac{100 - \text{percentage retained on the No. 10 sieve}}{100}$$

Diameter of Soil Particles in Suspension

11. (*a*) The maximum diameter of the particles in suspension, corresponding to the percentage indicated by a given hydrometer reading, shall be as indicated by Stokes' law.

$$\text{According to Stokes' law: } d = \sqrt{\frac{30nL}{980\,(G - G_1)\,T}}$$

where d = the maximum grain diameter in millimeters

n = the coefficient of viscosity of the suspending medium (in this case water) in poises. Varies with changes in temperature of the suspending medium.

L = the distance in centimeters through which soil particles settle in a given period of time

T = the time in minutes, period of sedimentation

G = the specific gravity of soil particles

G_1 = the specific gravity of the suspending medium. In this case $G_1 = 0.9984$, or approximately 1.0

(*b*) The maximum grain diameters in suspension for assumed conditions and corresponding to the periods of sedimentation specified in this procedure are given in Table I. These grain diameters shall be corrected for the conditions of the test by applying the proper correction factors as described and explained below.

TABLE I.—MAXIMUM GRAIN DIAMETERS IN SUSPENSION UNDER ASSUMED CONDITIONS.

TIME, MIN.	MAXIMUM GRAIN DIAMETER IN SUSPENSION, MM.
1	0.078
2	0.055
5	0.035
15	0.020
30	0.014
60	0.010
250	0.005
1440	0.002

(*c*) The grain diameters given in Table I are calculated according to the following assumptions:

L, the distance through which the particles fall, is constant and equal to 32.5 cm.

n, the coefficient of viscosity, equals 0.0102, that of water at 67 F. (19.4 C.).[1]

G, the specific gravity of the soil particles, is constant and equal to 2.65.

NOTE.—As a matter of fact, the hydrometer reading is dependent, not on the particles distributed throughout a depth of 32.5 cm. in the suspension, but on those existing in that portion of the suspension holding the hydrometer.

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[1] *Smithsonian Physical Tables*, 7th revised edition, 1921, p. 155.

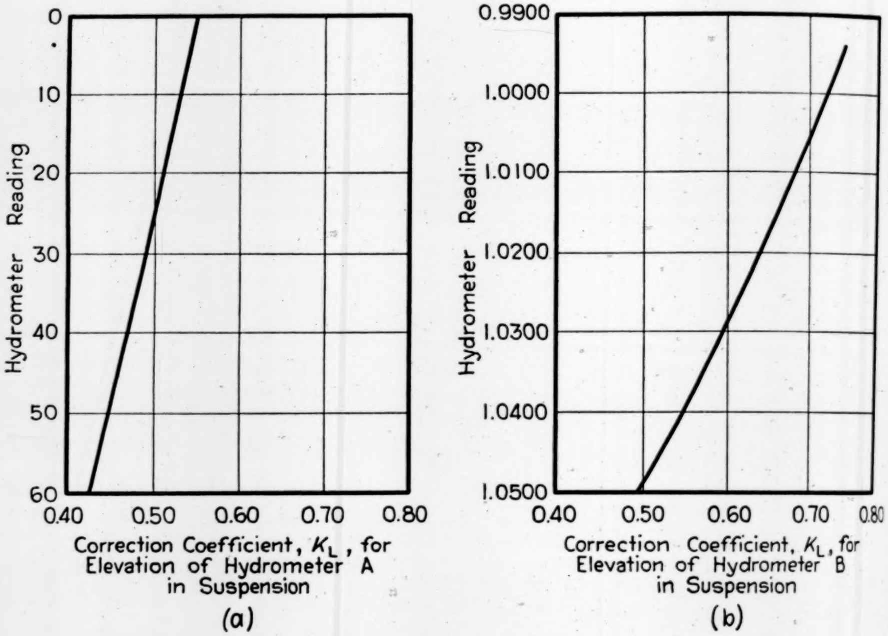

FIG. 7.—Correction Coefficient Curves for Elevation of Hydrometer.

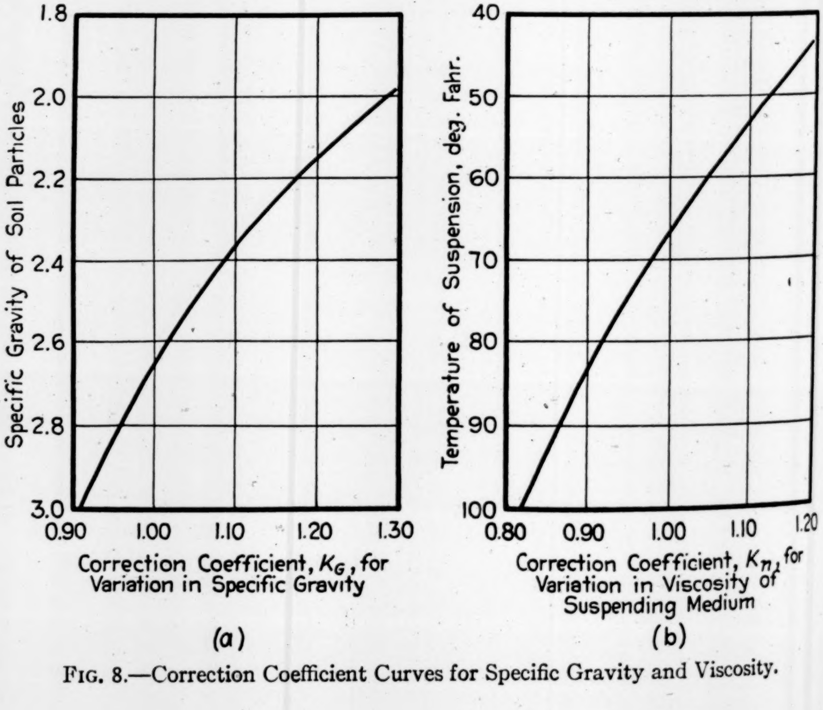

FIG. 8.—Correction Coefficient Curves for Specific Gravity and Viscosity.

(*d*) In order to use Stokes' law to determine the diameter of the particles it is necessary to know the distance through which these particles fall in a given time. Since the density throughout a suspension is not uniform and varies with the grading of the material in suspension and the time of sedimentation, a fixed distance cannot be used. For hydrometer *B* the depth of the center of volume of the hydrometer below the surface of the suspension can be taken as the distance through which the particles may be assumed to fall. In the case of hydrometer *A*, it has been found by experiment that for the methods of dispersion described in this procedure an assumed distance which bears a constant ratio to the depth of the hydrometer in the suspension, but which is less than the distance indicated by the center of volume of the hydrometer, gives closer agreement to mechanical analysis performed by the pipette methods. The assumed distance of fall is taken as 0.42 of the distance from the surface of the suspension to the elevation of the bottom of hydrometer *A*.

(*e*) The specific gravity of the soil particles and the temperature of the suspension are likely to vary from those assumed in the preparation of Table I. A better approximation of the true diameters of the soil particles is obtained by applying correction coefficients to the values given by Table I.

(*f*) Curves from which these coefficients may be derived are given in Figs. 7 and 8. The correction coefficients for elevation of hydrometer (Fig. 7 (*a*) and (*b*)) are obtained experimentally for each hydrometer in use. The coefficients for the specific gravity and the viscosity correction (Fig. 8 (*a*) and (*b*), respectively) are independent of the apparatus used in the test.

(*g*) Multiplication by the coefficients shown in Fig. 7 (*a*) and (*b*) gives the maximum grain size at the reference elevation of hydrometers *A* and *B*, respectively, instead of that at a depth of 32.5 cm. These coefficients vary with the hydrometer reading and may be obtained from the following formula:

$$K_L = \sqrt{\frac{\text{assumed depth of fall in centimeters}}{32.5}}$$

(*h*) Multiplication by the coefficients shown in Fig. 8 (*a*) corrects for variation in specific gravity from that on which the sizes given in Table I are based. These coefficients may be obtained from the following formula:

$$K_G = \sqrt{\frac{1.65}{\text{specific gravity of soil particle} - 1}}$$

(*i*) Multiplication by the coefficients shown in Fig. 8 (*b*) corrects for the viscosity of water at temperatures other than 67 F. (19.4 C.), the temperature of the suspension assumed in the preparation of Table I. The viscosity correction coefficient may be obtained from the following formula:

$$K_n = \sqrt{\frac{\text{viscosity coefficient at given temperature}}{0.0102}}$$

Example.—After a period of sedimentation of 1 min. the grain diameter indicated by Table I is 0.078 mm. Assume that the uncorrected reading of hydrometer *A* is 34, the specific gravity is 2.41, and the temperature of the suspension is 70 F. (21 C.). The correction coefficients in this case are 0.48, corresponding to a hydrometer reading of 34 (Fig. 7 (*a*)); 1.08, corresponding to a specific gravity of 2.41 (Fig. 8 (*a*)); and 0.98, corresponding to a water temperature of 70 F. (21 C.) (Fig. 8 (*b*)). The corrected grain diameter then becomes:

$$0.078 \text{ mm.} \times 0.48 \times 1.08 \times 0.98 = 0.040 \text{ mm.}$$

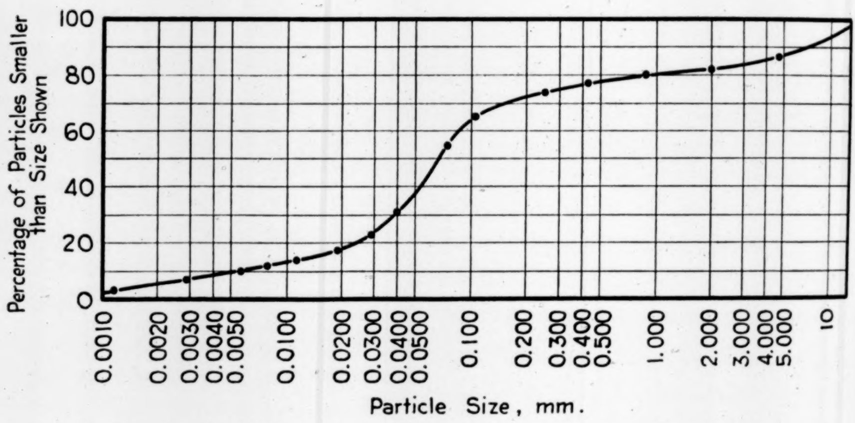

FIG. 9.—Grain Size Accumulation Curve, Soil Sample No. 4422X.

Sieve Analysis

12. (*a*) The percentage of the dispersed soil sample retained on each of the sieves in the sieve analysis shall be obtained by dividing the weight of fraction retained on each sieve by the oven-dry weight of the dispersed soil and multiplying by 100.

(*b*) The percentages of the total test sample, including the fraction retained on the No. 10 sieve, shall be obtained by multiplying these values by the expression:

$$\frac{100 - \text{percentage retained on the No. 10 sieve}}{100}$$

Plotting

13. The percentages of grains of different grain diameters shall be plotted on semilogarithmic paper to obtain a "soil grain diameter accumulation curve." A curve of this character is shown in Fig. 9.

Report

14. The results, read from the accumulation curve, shall be reported as follows:

(*a*) Percentage of particles larger than 2 mm.
(*b*) Percentage of coarse sand, 2.0 to 0.25 mm.
(*c*) Percentage of fine sand, 0.25 to 0.05 mm.
(*d*) Percentage of silt, 0.05 to 0.005 mm.
(*e*) Percentage of clay, smaller than 0.005 mm.
(*f*) Percentage of colloids, smaller than 0.001 mm.

TENTATIVE METHOD OF TEST FOR LIQUID LIMIT OF SOILS[1]

A.S.T.M. Designation: D 423 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Liquid Limit

1. The liquid limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil will just begin to flow when lightly jarred ten times.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(*c*) *Mechanical Device.*—A mechanical device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Fig. 1.

(*d*) *Grooving Tool.*—A combined grooving tool and gage conforming to the dimensions shown in Fig. 1.

(*e*) *Watch Glasses.*—Matched watch glasses which are held together by a suitable clamp and fit sufficiently tight to prevent loss of moisture during weighing.

(*f*) *Balance.*—An analytical balance sensitive to 0.001 g.

HAND METHOD

Sample

3. A sample weighing about 30 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 35 T) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] See p. 950.

Procedure

4. (*a*) The air-dried soil shall be placed in the evaporating dish and thoroughly mixed with distilled water until the mass becomes pasty. The mass of soil shall then be shaped into a small layer about $\frac{3}{8}$ in. in thickness at the center and divided into two portions with the grooving tool, as shown in the illustration at the top of Fig. 2.

(*b*) The dish shall be held firmly in one hand, with the groove parallel to the line of sight, and tapped lightly with a horizontal motion against the palm of the other hand ten times. The intensity of the blows shall be such that the effect on the soil sample is equivalent to that produced by 25 shocks applied to a sample of the soil at the same moisture content by dropping the brass cup of the mechanical device through a distance of 1 cm. (0.3937 in.) at the rate of two drops per second.

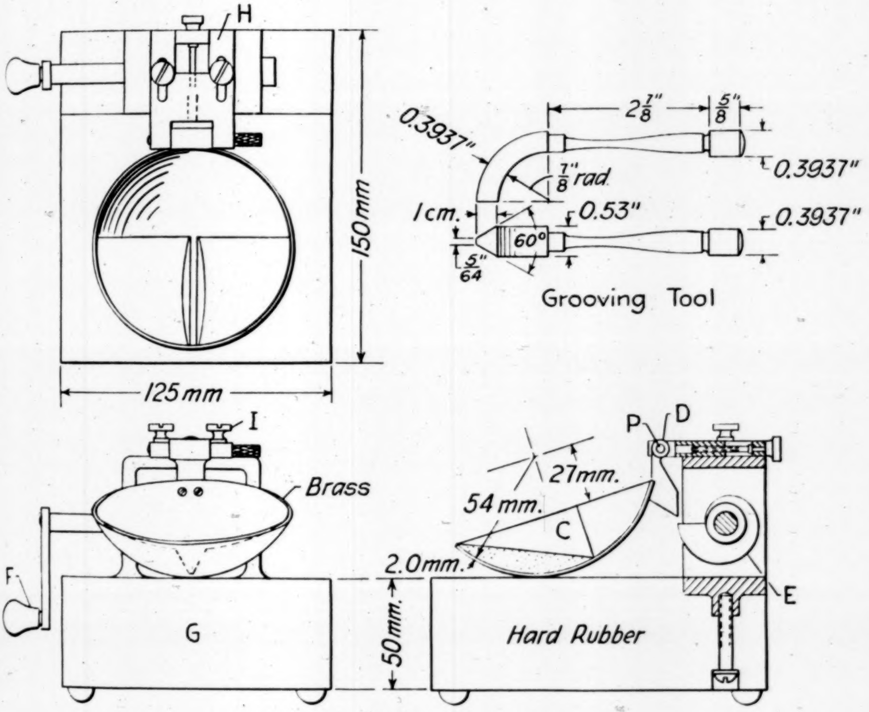

FIG. 1.—Liquid Limit Device.

(*c*) If the lower edges of the two soil portions do not flow together, as shown in the illustration at the bottom of Fig. 2, after ten blows have been struck, the moisture content is below the liquid limit. More water shall be added and the procedure repeated. If the lower edges meet before ten blows have been struck, the moisture content is above the liquid limit, and dry soil shall be added and the procedure repeated.

(*d*) When the lower edges of the two portions of the soil cake just flow together as shown in the illustration at the bottom of Fig. 2 after ten blows have been struck, the moisture content equals the liquid limit. To determine definitely whether the two portions are actually joined, the spatula may be used to push one away from the other. If the two portions separate along the original line of division, the end point has not been reached, and the procedure shall be repeated with the addition of a small amount of water.

(*e*) A small quantity of soil from that portion of the soil cake which has flowed shall be removed and placed in a pair of watch glasses. The watch glasses and soil shall then be weighed and the weight recorded.

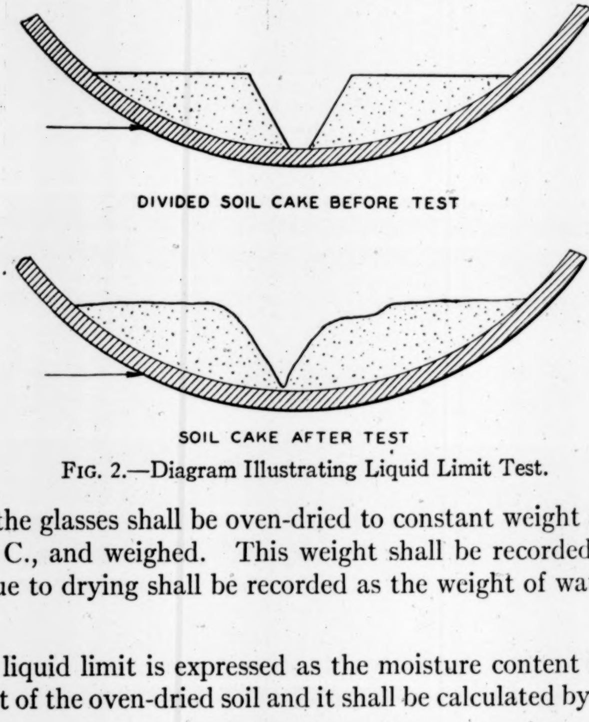

FIG. 2.—Diagram Illustrating Liquid Limit Test.

The soil in the glasses shall be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.

Calculation

5. The liquid limit is expressed as the moisture content in percentage of the weight of the oven-dried soil and it shall be calculated by the following formula:

$$\text{Liquid limit} = \frac{\text{weight of water}}{\text{weight of oven-dry soil}} \times 100$$

MECHANICAL METHOD

Calibration of Mechanical Device

6. By means of the gage attached to the grooving tool, and the adjustment plate, *H*, Fig. 1, the height to which the cup, *C*, is lifted shall be adjusted so that the point on the cup which comes in contact with the base is

exactly 1 cm. (0.3937 in.) above the base. The adjustment plate, *H*, shall then be secured by tightening the screws, *I*.

Procedure

7. (*a*) A sample weighing about 100 g. shall be taken from the thoroughly mixed portion of the air-dried soil passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 35 T) of the American Society for Testing Materials.[1] This sample shall be placed in the evaporating dish and thoroughly mixed with a measured quantity of distilled water to a pasty consistency. A portion of this paste shall then be placed in the brass cup in the position shown in Fig. 1, leveled off to a depth of 1 cm., and divided by means of the grooving tool along the diameter through the centerline of the cam follower.

(*b*) The cup shall then be attached to the carriage and by turning the crank, *F*, at the rate of two rotations per second lifted and dropped until the two sides of the sample come into contact at the bottom of the groove along a distance of about $\frac{1}{2}$ in. The number of shocks shall be recorded. The moisture content of the soil shall then be determined on a portion taken from around the groove, by the method previously described in Section 4 in connection with the hand method.

(*c*) The foregoing operations shall be repeated with samples of the soil at two or more additional moisture contents both above and below that requiring about 25 blows for closure of the groove.

Preparation of Flow Curve

8. A "flow curve" representing the relation between moisture contents and corresponding numbers of shocks shall be plotted on a semi-log graph with the moisture contents as abscissae on the arithmetical scale, and the numbers of shocks as ordinates on the logarithmic scale.

Liquid Limit Determination

9. The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil.

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[1] See p. 950.

TENTATIVE METHOD OF TEST
FOR
PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS[1]

A.S.T.M. Designation: D 424 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.[2]

Plastic Limit

1. The plastic limit of a soil is the lowest moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil can be rolled into threads $\frac{1}{8}$ in. in diameter without the threads breaking into pieces.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish*.—A porcelain evaporating dish about 4½ in. in diameter.

(*b*) *Spatula*.—A spatula or pill knife having a blade about 3 in. in length and about ¾ in. in width.

(*c*) *Surface for Rolling*.—A glass plate or piece of glazed paper on which to roll the sample.

(*d*) *Watch Glasses*.—Matched watch glasses which are held together by a suitable clamp and fit sufficiently tight to prevent loss of moisture during weighing.

(*e*) *Balance*.—An analytical balance sensitive to 0.001 g.

Sample

3. A sample weighing about 15 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve, which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 35 T) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

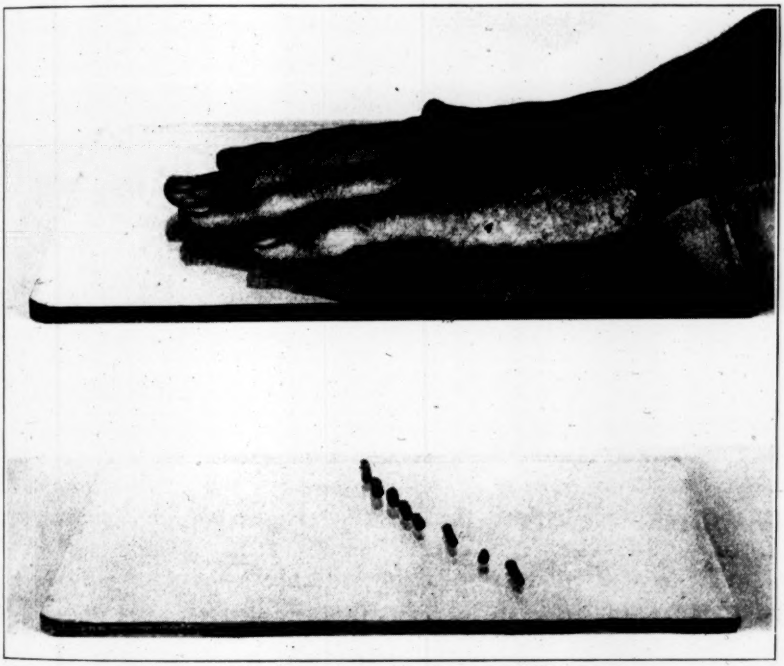
[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] See p. 950.

Procedure

4. The air-dried soil shall be placed in the evaporating dish and mixed with distilled water until the mass becomes plastic enough to be easily shaped into a ball. The ball of soil shall then be rolled between the palm of the hand and the glass plate or piece of glazed paper with just sufficient pressure to form the soil mass into a thread (Fig. 1 (*a*)). When the diameter of the resulting thread becomes $\frac{1}{8}$ in. the soil shall be kneaded together and again rolled out. This process shall be continued until the crumbling of the soil (as shown in Fig. 1 (*b*)) prevents the formation of the thread. The portions of the crumbled soil shall then be gathered together and placed in watch glasses. The watch glasses and soil shall be weighed and the weight recorded. The soil in the glasses shall then be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the loss in weight shall be recorded as the weight of water.

(*a*) Rolling of soil threads in plastic limit test.



(*b*) Crumbled soil threads resulting from plastic limit test.

FIG. 1.—Plastic Limit Test.

Calculation

5. The plastic limit is expressed as the moisture content in percentage of the weight of the oven-dry soil and shall be calculated by the following formula:

$$\text{Plastic limit} = \frac{\text{weight of water}}{\text{weight of oven-dry soil}} \times 100$$

Plasticity Index

6. The plasticity index of a soil is the difference between its liquid limit and its plastic limit.

7. The plasticity index shall be calculated by the following formula:

$$\text{Plasticity index} = \text{liquid limit} - \text{plastic limit}$$

NOTE.—Liquid limit shall be determined in accordance with the Tentative Method of Test for Liquid Limit of Soils (A.S.T.M. Designation: D 423 - 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 956.

TENTATIVE METHOD OF TEST
FOR
CENTRIFUGE MOISTURE EQUIVALENT OF SOILS[1]

A.S.T.M. Designation: D 425 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Centrifuge Moisture Equivalent

1. The centrifuge moisture equivalent of a soil is the amount of moisture, expressed as a percentage of the weight of the oven-dried soil, retained by a soil which has been first saturated with water and then subjected to a force equal to one thousand times the force of gravity for one hour.

Apparatus

2. The apparatus shall consist of the following:

(a) *Gooch Crucible.*—A porcelain Gooch crucible with perforated bottom. The crucible shall be about $1\frac{1}{2}$ in. in height and the diameter shall be about 1 in. at the top and $\frac{3}{4}$ in. at the bottom, outside dimensions.

(b) *Filter Paper.*—A circular piece of filter paper just large enough to cover the inside bottom of the Gooch crucible.

(c) *Trunnion Cup.*—A Babcock trunnion cup fitted with a brass cap and with a suitable device for supporting the Gooch crucible $\frac{1}{2}$ in. above the bottom of the cup in such a manner that the water ejected during the centrifuging operation shall not come in contact with the crucible and contents and, furthermore, that air may circulate freely about the crucible within the cup. Suitable fittings for the Babcock cup are shown in Fig. 1.

(d) *Centrifuge.*—The centrifuge shall be of such size and so driven that a force equal to one thousand times the force of gravity may be exerted on the center of gravity of the soil sample.

(e) *Balance.*—An analytical balance sensitive to 0.001 g.

Sample

3. A 5-g. sample shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards ,August 22, 1935.

Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 – 35 T) of the American Society for Testing Materials.[1]

Number of Tests

4. Tests shall be made in duplicate.

Procedure

5. (*a*) The sample shall be placed in the Gooch crucible, in which has previously been placed a piece of wet filter paper which just covers the bottom of the crucible. The crucible shall be placed in a pan of distilled water and the sample allowed to take up moisture until completely saturated, as indicated by the presence of free water on the surface of the sample. It shall then be placed in a humidifier for at least 12 hr. to insure uniform distribution of moisture throughout the soil mass. All free water then remaining on the surface of the sample shall be poured off, and the crucible placed in a Babcock trunnion cup fitted as described in Section 2 (*c*).

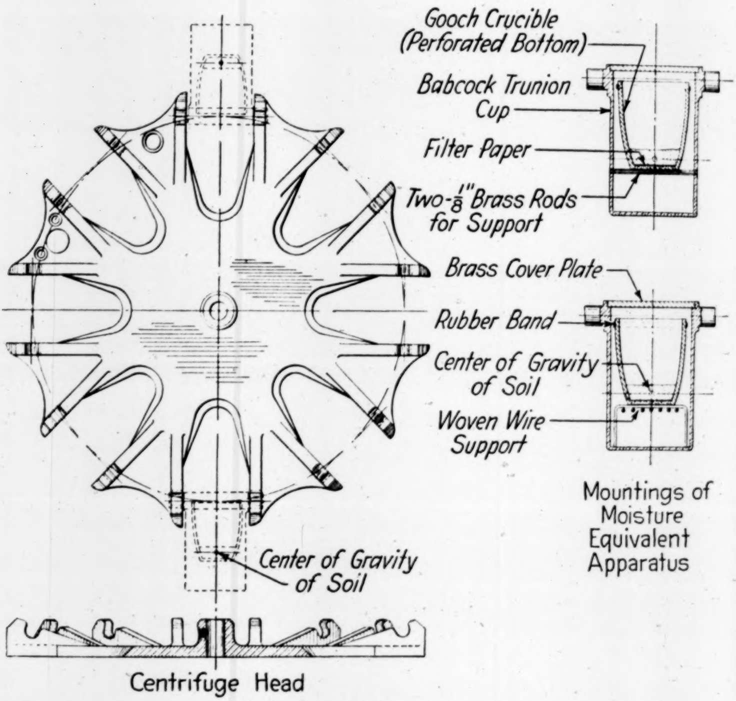
Gooch Crucible (Perforated Bottom)
Babcock Trunion Cup
Filter Paper
Two-$\frac{1}{8}$" Brass Rods for Support
Brass Cover Plate
Rubber Band
Center of Gravity of Soil
Woven Wire Support
Mountings of Moisture Equivalent Apparatus
Center of Gravity of Soil
Centrifuge Head

FIG. 1.—Centrifuge Apparatus.

(*b*) The sample shall be centrifuged for a period of 1 hr. at a speed which, for the diameter of head used, will exert a centrifugal force one thousand times the force of gravity upon the center of gravity of the soil sample. Immediately after centrifuging, the crucible and contents shall be weighed and the weight recorded as the weight of crucible and contents after centrifuging. The sample shall then be oven dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded as the weight of crucible and contents after drying.

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[1] See p. 950.

(*c*) *Water-logging.*—When free water is observed on the top of the sample after the centrifuging operation, the soil is said to have water-logged. This water shall not be removed but shall be weighed with the sample.

Calculation

6. The centrifuge moisture equivalent of the soil shall be calculated by the following formula:

$$\text{Centrifuge moisture equivalent} = \frac{(A - b) - (A_1 - b_1)}{A_1 - (c + b_1)} \times 100$$

where A = the weight of crucible and contents after centrifuging
A_1 = the weight of crucible and contents after drying
c = the weight of crucible
b = the weight of filter paper wet
b_1 = the weight of filter paper dry

Permissible Variation in Duplicate Tests

7. The variation between the two values obtained in the duplicate tests should not exceed 1 per cent for values of the moisture equivalent up to 15 and 2 per cent for values above 15.

TENTATIVE METHOD OF TEST
FOR
FIELD MOISTURE EQUIVALENT OF SOILS[1]

A.S.T.M. Designation: D 426 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Field Moisture Equivalent

1. The field moisture equivalent of a soil is defined as the minimum moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a drop of water placed on a smoothed surface of the soil will not immediately be absorbed by the soil but will spread out over the surface and give it a shiny appearance.

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(*c*) *Pipette.*—A pipette, burette, or similar device for adding water dropwise.

(*d*) *Watch Glasses.*—Matched watch glasses, held together by a suitable clamp and fitting sufficiently tight to prevent loss of moisture during weighing.

(*e*) *Balance.*—An analytical balance sensitive to 0.001 g.

Sample

3. A sample weighing about 50 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve, which has been obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation D 421 - 35 T) of the American Society for Testing Materials.[3]

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

[3] See p. 950.

Procedure

4. The air-dried sample shall be placed in the evaporating dish and mixed with distilled water. Distilled water shall be added in small amounts and the sample thoroughly mixed after each addition of water. When the wetted soil forms into balls under manipulation, the sample shall be smoothed with a light stroke of the spatula and a drop of water placed on the smoothed surface. If the water disappears in 30 sec. a few more drops of water shall be added, and the procedure shall be repeated until the water does not disappear in 30 sec. but spreads over the smoothed surface and leaves a shiny appearance. A small portion of the soil on which the last drop of water was placed shall then be removed and placed between two watch glasses. The weight of the watch glasses and wet soil shall be determined and recorded. The sample shall then be oven-dried to constant weight at a temperature of 110 C., and weighed. This weight shall be recorded and the difference in weight shall be recorded as the weight of water.

Calculation

5. The field moisture equivalent shall be calculated by the following formula:

$$\text{Field moisture equivalent} = \frac{\text{weight of water}}{\text{weight of oven-dried soil}} \times 100$$

TENTATIVE METHOD OF TEST
FOR
SHRINKAGE FACTORS OF SOILS[1]

A.S.T.M. Designation: D 427 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method furnishes the data from which the following subgrade soil constants may be calculated:

Shrinkage Limit
Shrinkage Ratio
Volumetric Change
Lineal Shrinkage
Specific Gravity (Approximate)

Apparatus

2. The apparatus shall consist of the following:

(*a*) *Evaporating Dish.*—A porcelain evaporating dish about $4\frac{1}{2}$ in. in diameter.

(*b*) *Spatula.*—A spatula or pill knife having a blade about 3 in. in length and about $\frac{3}{4}$ in. in width.

(*c*) *Porcelain Dish.*—A circular porcelain milk dish having a flat bottom and being about $1\frac{3}{4}$ in. in diameter by about $\frac{1}{2}$ in. in height.

(*d*) *Straight Edge.*—A steel straight edge about 12 in. in length.

(*e*) *Glass Cup.*—A glass cup about 2 in. in diameter and about 1 in. in height, the top rim of which is ground smooth and level.

(*f*) *Glass Plate.*—A glass plate with three metal prongs for immersing the soil pat in mercury, as shown in Fig. 1.

(*g*) *Graduate.*—A glass graduate having a capacity of 25 cc. and graduated to 0.2 cc.

(*h*) *Balance.*—An analytical balance sensitive to 0.001 g.

(*i*) *Mercury.*—Sufficient mercury to fill the glass cup to overflowing.

Sample

3. A sample weighing about 30 g. shall be taken from the thoroughly mixed portion of the material passing the No. 40 sieve which has been

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-4 on Road and Paving Materials.
[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

obtained in accordance with the Tentative Method of Preparing Soil Samples as Received from the Field for Mechanical Analysis and the Determination of the Subgrade Soil Constants (A.S.T.M. Designation: D 421 - 35 T) of the American Society for Testing Materials.[1]

Procedure

4. (*a*) The sample shall be placed in the evaporating dish and thoroughly mixed with distilled water in amount sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into the porcelain milk dish without the inclusion of air bubbles. The amount of water required to furnish friable soils with the desired consistency is equal to or slightly greater than the liquid limit, and the amount necessary to furnish plastic soils with the desired consistency may exceed the liquid limit by as much as 10 per cent.

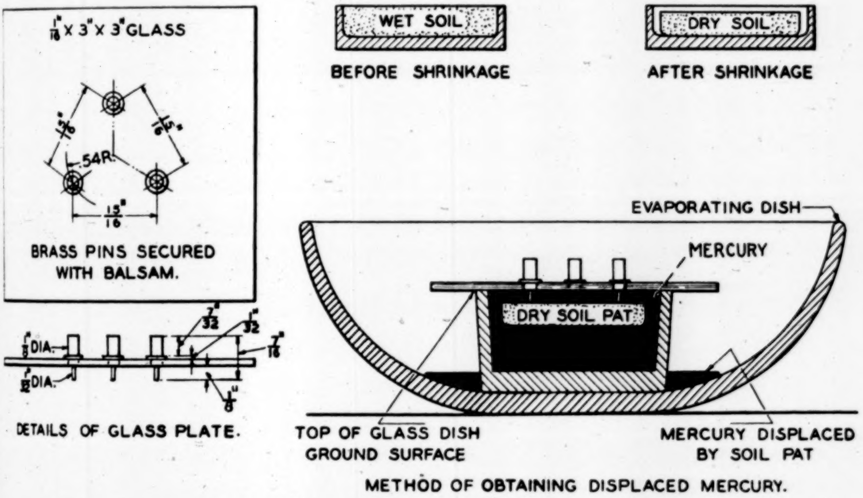
1/16" x 3" x 3" GLASS
.54R
15/16"
BRASS PINS SECURED WITH BALSAM.
1/8" DIA.
3/32" DIA.
7/32"
1/32"
7/16"
1/8"
DETAILS OF GLASS PLATE.
WET SOIL
BEFORE SHRINKAGE
DRY SOIL
AFTER SHRINKAGE
EVAPORATING DISH
MERCURY
DRY SOIL PAT
TOP OF GLASS DISH GROUND SURFACE
MERCURY DISPLACED BY SOIL PAT
METHOD OF OBTAINING DISPLACED MERCURY.

FIG. 1.—Apparatus for Determining the Volumetric Change of Subgrade Soils.

(*b*) The inside of the porcelain milk dish shall be coated with a thin layer of vaseline or some other heavy grease to prevent the adhesion of the soil to the dish. An amount of the wetted soil equal to about one-third the volume of the milk dish shall be placed in the center of the dish, and the soil caused to flow to the edges by tapping the dish on a firm surface cushioned by several layers of blotting paper or similar material. An amount of soil shall be added approximately equal to the first portion, and the dish tapped until the soil is thoroughly compacted and all included air has been brought to the surface. More soil shall be added and the tapping shall be continued until the dish is completely filled and excess soil stands out about its edge. The excess soil shall then be struck off with a straight edge, and all soil adhering to the outside of the dish shall be wiped off.

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[1] See p. 950.

(*c*) The dish when filled and struck off shall be weighed immediately and the weight recorded as the weight of dish and wet soil. The soil pat shall be allowed to dry in air until the color of the pat turns from dark to light. It shall then be oven-dried to constant weight at 110 C. and weighed, the weight being recorded as the weight of dish and dry soil. The weight of the empty dish shall be determined and recorded. The capacity of the dish in cubic centimeters, which is also the volume of the wet soil pat, shall be determined by filling the dish to overflowing with mercury, removing the excess by pressing a glass plate firmly over the top of the dish, and measuring by means of a glass graduate the volume of mercury held in the dish. This volume shall be recorded as the volume of the wet soil pat, V.

(*d*) The volume of the dry soil pat shall be determined by removing the pat from the porcelain milk dish and immersing it in the glass cup full of mercury in the following manner: The glass cup shall be filled to overflowing with mercury and the excess mercury shall be removed by pressing the glass plate with the three prongs (Fig. 1) firmly over the top of the cup. Any mercury which may be adhering to the outside of the cup shall be carefully wiped off. The cup, filled with mercury, shall be placed in the evaporating dish, and the soil pat shall be placed on the surface of the mercury. It shall then be carefully forced under the mercury by means of the glass plate with the three prongs (Fig. 1) and the plate shall be pressed firmly over the top of the cup. It is essential that no air be trapped under the soil pat. The volume of the mercury so displaced shall be measured in the glass graduate and recorded as the volume of the dry soil pat, V_o).

Calculation of Moisture Content

5. The moisture content of the soil at the time it was placed in the dish expressed as a percentage of the dry weight of the soil shall be calculated from the formula:

$$w = \frac{W - W_o}{W_o} \times 100$$

where w = the moisture content of the soil when placed in the dish.

W = the weight of the wet soil pat obtained by subtracting the weight of the porcelain milk dish from the weight of the dish and wet pat.

W_o = the weight of the dry soil pat obtained by subtracting the weight of the porcelain milk dish from the weight of the dish and dry pat.

Shrinkage Limit

6. The shrinkage limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which a reduction in

moisture content will not cause a decrease in the volume of the soil mass, but at which an increase in moisture content will cause an increase in the volume of the soil mass.

Calculation of Shrinkage Limit

7. (*a*) The shrinkage limit, S, shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$S = w - \left(\frac{V - V_o}{W_o} \times 100\right)$$

where S = the shrinkage limit

w = the moisture content of the wet soil, in percentage of the weight of oven-dried soil

V = the volume of wet soil pat

V_o = the volume of dry soil pat

W_o = the weight of oven-dried soil pat.

(*b*) *Optional Method.*—When both the true specific gravity, G, and the shrinkage ratio, R, are known, the shrinkage limit may be calculated from the following formula:

$$S = \left(\frac{1}{R} - \frac{1}{G}\right) \times 100$$

Shrinkage Ratio

8. The shrinkage ratio of a soil is the ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in moisture content above the shrinkage limit, expressed as a percentage of the weight of the oven-dried soil. It equals the apparent specific gravity of the dried soil pat.

Calculation of Shrinkage Ratio

9. The shrinkage ratio, R, shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$R = \frac{W_o}{V_o}$$

Volumetric Change

10. The volumetric change of a soil for a given moisture content is the volume change, expressed as a percentage of the dry volume, of the soil mass when the moisture content is reduced from the stipulated percentage to the shrinkage limit. This stipulated moisture content is usually taken as the field moisture equivalent.

Calculation of Volumetric Change

11. The volumetric change shall be calculated from the data obtained in the volumetric shrinkage determination by the following formula:

$$\text{Volumetric change} = (w_1 - S)R$$

where w_1 = the given moisture content

If, as is customary, the volumetric change from the field moisture equivalent is desired, the formula assumes the following form:

Volumetric change, C_f = volumetric change from field moisture equivalent
Volumetric change = (field moisture equivalent $- S)R$

Lineal Shrinkage

12. The lineal shrinkage of a soil for a given moisture content is the decrease in one dimension, expressed as a percentage of the original dimension, of the soil mass when the moisture content is reduced from an amount equal to the field moisture equivalent to the shrinkage limit.

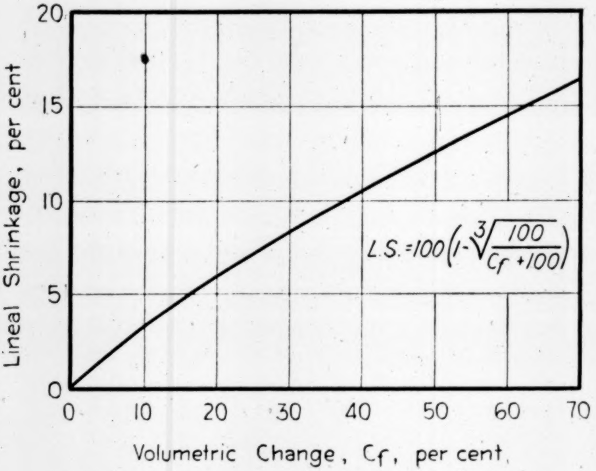

FIG. 2.—Curve for Determining Lineal Shrinkage.

Calculation of Lineal Shrinkage

13. The lineal shrinkage shall be obtained either by means of the following formula or by means of the curve shown in Fig. 2, which represents this relation:

$$\text{Lineal shrinkage} = 100\left(1 - \sqrt[3]{\frac{100}{C_f + 100}}\right)$$

Specific Gravity

14. The specific gravity of a soil is the weight of the oven-dried soil divided by the true volume of the soil particles.

Calculation of Specific Gravity

15. The specific gravity may be calculated from the data obtained in the volumetric shrinkage test by the following formula:

$$\text{Sp. Gr.} = \frac{1}{\frac{1}{R} - \frac{S}{100}}$$

TENTATIVE SPECIFICATIONS

FOR

ASPHALT FOR USE IN CONSTRUCTING BUILT-UP ROOF COVERINGS[1]

A.S.T.M. Designation: D 312 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1929; REVISED, 1935.

Scope

1. These specifications cover asphalt intended for use as hot-cement and mopping coat in the construction of built-up roof coverings for roofs surfaced in various manners, laid either over boards or concrete on various inclines, in connection with the Standard Specifications for Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-Up Roofs (A.S.T.M. Designation: D 226)[2] or the Standard Specifications for Asphalt-Saturated Asbestos Felt for Use in Constructing Built-Up Roofs (A.S.T.M. Designation: D 250)[3] of the American Society for Testing Materials.

Types

2. The asphalts covered by these specifications are as follows:

(*a*) Relatively susceptible asphalts with good adhesive and "self-healing" properties for use in slag or gravel surfaced roofing on inclines up to 3 in. per ft.;

(*b*) Somewhat less susceptible asphalts for unsurfaced roofing on inclines up to 3 in. per ft., and

(*c*) Relatively non-susceptible asphalts for use on inclines between 3 and 6 in. per ft.

Properties

3. The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1049.

[3] *Ibid.*, p. 1012.

	Type of Roofing					
	Mineral Surfaced Flat		Unsurfaced Flat		Unsurfaced Steep	
	Min.	Max.	Min.	Max.	Min.	Max.
For use on decks having inclines:						
Over boards, in. per ft	....	3	....	3	3	6
Over concrete, in. per ft	....	3	....	3	3	6
(*a*) Softening point (Ring-and-Ball Method)	135 F. (57 C.)	150 F. (66 C.)	135 F. (57 C.)	170 F. (77 C.)	170 F. (77 C.)	200 F. (93 C.)
(*b*) Penetration:						
0 C. (32 F.), 200 g., 60 sec	5	....	5	....	10	....
25 C. (77 F.), 100 g., 5 sec	20	50	20	40	20	40
46 C. (115 F.), 50 g., 5 sec	100	....	....	150	....	100
(*c*) Ductility at 25 C. (77 F.), (5 cm. per min.), cm	10	....	4	....	3	....
(*d*) Loss on heating at 163 C. (325 F.), 50 g., 5 hr., per cent	....	1.5	....	1.5	....	1.5
(*e*) Penetration of residue, per cent original	60	....	60	....	60	....
(*f*) Soluble in carbon disulfide:						
Filled or native asphalt, per cent	65	....	65	....	65	....
Unfilled asphalt, per cent	99	....	99	....	99	....
(*g*) Bitumen soluble in carbon tetrachloride, per cent	99	....	99	....	99	....
(*h*) Ash:						
Filled or native asphalt, per cent	7.5	35	7.5	35	7.5	35
Unfilled asphalt, per cent	....	1	....	1	....	1
(*i*) Coarse particles retained on No. 200 sieve as percentage of ash, per cent	....	15	....	15	....	15

Sampling and Methods of Testing

4. The asphalt shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Sampling.*—Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140).[1]

(*b*) *Softening Point.*—Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (A.S.T.M. Designation: D 36).[2]

(*c*) *Penetration.*—Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5).[3]

(*d*) *Loss on Heating.*—Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (A.S.T.M. Designation: D 6).[4]

(*e*) *Ductility.*—Standard Method of Test for Ductility of Bituminous Materials (A.S.T.M. Designation: D 113).[5]

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 974.

[2] *Ibid.*, p. 984.

[3] *Ibid.*, p. 971.

[4] *Ibid.*, p. 962.

[5] 1935 Supplement to Book of A.S.T.M. Standards, p. 194.

(*f*) *Soluble in Carbon Disulfide.*—Standard Method of Test for the Determination of Bitumen (A.S.T.M. Designation: D 4).[1]

(*g*) *Ash.*—Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271).[2]

(*h*) *Soluble in Carbon Tetrachloride.*—Standard Method of Test for the Determination of Proportion of Bitumen Soluble in Carbon Tetrachloride (A.S.T.M. Designation: D 165).[3]

(*i*) *Coarse Particles.*—Tentative Method of Test for Coarse Particles in Mixtures of Asphalt and Mineral Matter (A.S.T.M. Designation: D 313 – 35 T).[4]

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 945.

[2] *Ibid.*, p. 269.

[3] *Ibid.*, p. 948.

[4] See p. 1001.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT ROOFING SURFACED WITH COARSE MINERAL GRANULES[1]

A.S.T.M. Designation: D 249 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1926; ADOPTED, 1927; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications cover asphalt roofing in sheet form surfaced with colored mineral granules, either 36 or 32 in. in width, composed of roofing-felt saturated and coated on both sides with asphalt and surfaced on the weather side with granulated slate or equivalent mineral material (of solid or mixed colors as may be mutually agreed upon between the purchaser and seller), and on the reverse side with powdered talc or mica.

Manufacture

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant, then coated on both sides with a hot asphaltic coating compounded with a fine mineral filler substantially insoluble in water, and finally surfaced on the weather side with mineral granules embedded in the hot asphaltic coating. The reverse side shall be covered with powdered talc or mica to prevent the roofing from sticking together in the package.

Character of Felt

3. The felt shall be composed of a continuous sheet of "felted" vegetable and animal fibers. Its surface shall be uniformly smooth and free from lumps of unbeaten stock and particles of hard foreign substances.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of the former Standard Specifications for Heavy Weight Asphalt Roll-Roofing and Heavy Weight Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 249 - 27), which standard was accordingly discontinued in 1933.

Character of Saturant and Coatings

4. The saturant and coatings shall be composed principally of asphaltic materials.

Physical Properties

5. The fabricated product shall conform to the following requirements:

(*a*) *Width.*—The roofing shall be put up in rolls and shall be either 36 or 32 in. in width, as may be specified, within a permissible variation of $\pm\frac{1}{4}$ in.

(*b*) *Area.*—The average area of the rolls examined shall contain sufficient roofing to cover 100 sq. ft. of roof surface (108 sq. ft. with 2 in. or no bare lapping edge, or 111 sq. ft. with 3 in. lapping edge).

	MAX., LB.	MIN., LB.
(*c*) Weight per roll, net avg... No bare edge	....	83.0
2 or 3 in. bare edge	....	81.0
(*d*) Weight of dry felt per 108 sq. ft.	....	10.8
(*e*) Weight of saturant (soluble in CS_2) per 108 sq. ft.[a]	....	17.3
(*f*) Weight of weather side coating (soluble in CS_2) per 108 sq. ft.	20.0	12.0
(*g*) Weight of reverse side coating (soluble in CS_2) per 108 sq. ft.	5.0	2.0
(*h*) Weight of mineral matter per 108 sq. ft. passing No. 6 and retained on No. 100 sieve	40.0	25.0
(*i*) Weight of mineral matter per 108 sq. ft. passing No. 100 sieve	10.0	4.0
(*j*) Weight of any 108 sq. ft. roll of complete roofing in the shipment (coarse granule surfaced portion)	....	80.0
(*k*) Pliability at 77 F. (25 C.)	at least 8 strips out of 10 shall not crack when bent 90 deg. at a uniform speed over a rounded corner of $\frac{3}{4}$-in. radius.	
(*l*) Behavior on heating to 176 F. (80 C.) for 2 hr	not more than 1.5 per cent volatile matter loss. The granular surfacing shall not slide more than $\frac{1}{16}$ in. when suspended vertically.	

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[a] The weight of saturant per 108 sq. ft. shall be not less than 1.6 times the weight of the dry felt.

Surface Finish

6. (*a*) The surface of the weather side shall be uniform in finish and texture. The mineral granules shall be uniformly distributed over the entire surface (except as noted in Paragraph (*b*)) in a smooth layer and shall be firmly embedded in the asphalt coating.

(*b*) The coating and granules shall cover the entire weather side of the roofing, except that this side may be provided with a bare lapping edge, approximately 2 or 3 in. in width along one edge, where either the granules alone or both the granules and coating may be omitted.

(*c*) The reverse side of the sheet shall have the asphalt coating and powdered surfacing applied uniformly to the edges.

Distribution of Coating and Surfacing

7. The felt shall be completely and uniformly saturated, and shall show no unsaturated spots at any point when the roofing is cut or split open.

Packing

9. (*a*) The roofing shall be put up in rolls of either 108 sq. ft. when made with a 2-in. or no bare-lapping edge or 111 sq. ft. when made with a 3-in. bare-lapping edge. No roll shall contain more than two pieces nor shall there be more than 3 per cent of the rolls containing two pieces in any shipment. The rolls shall be tightly wound, and securely wrapped with a substantial grade of paper completely encircling the roll, and pasted at the overlap in such a manner as to prevent shifting from position. The ends of the rolls shall be protected with cloth covers or by other suitable means. The nails and lap-cement shall be packed in the core of each roll or furnished separately if so specified by the purchaser.

(*b*) Each roll shall be plainly marked with the manufacturer's name and brand. Special packing shall be as agreed upon between the purchaser and seller.

Nails and Lap-Cement

10. (*a*) *Nails.*—The gage of the wire shall not be greater than Washburn & Moen No. 10 (0.135 in.) nor thinner than No. 12 (0.105 in.); the head shall not be less than $\frac{3}{8}$ in. in diameter, and not less than 0.025 in. in thickness; the shank shall be between $\frac{3}{4}$ and 1 in. in length, with its lower end pointed, and shall be either smooth or barbed, and if the latter, then the barbings shall not increase the diameter of the lower two-thirds more than 0.01 in. The nails shall be zinc coated with not less than $\frac{1}{2}$ oz. nor more than $1\frac{1}{4}$ oz. per sq. ft. of nail surface. Hot-galvanized, electrogalvanized, or sherardized coatings will be accepted. There shall be furnished per "square" not less than an average of 252 nails for 36-in. roofing, and not less than an average of 275 nails for 32-in. roofing.

(*b*) *Lap-Cement.*—The cement shall be composed of bituminous materials dissolved in a volatile solvent, and shall be of such a nature as to firmly bind the laps without injurious effect upon the roofing. The cement shall have a minimum flash point of 71 F. (21.5 C.) when tested by the Tag Closed-Cup Tester. There shall be furnished for each "square" of 36-in. roofing not less than ¾ pt. of cement and for 32-in. roofing not less than 1 pt. of cement. The addition of 5 to 20 per cent by weight of short-fibered asbestos shall be permitted, in which case the quantity of cement shall be increased by ¼ pt. per "square."

(*c*) *Special Fixtures.*—Special fixtures may be furnished in lieu of nails and cement, if agreed upon by the purchaser and seller.

Sampling and Testing

11. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules; also Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 228 – 33 T) of the American Society for Testing Materials.[1]

Inspection

12. Inspection of material shall be made as mutually agreed upon by the purchaser and seller as part of the purchase contract.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 799 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 941.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT ROOFING SURFACED WITH FINE MINERAL GRANULES[1]

A.S.T.M. Designation: D 248 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1926; ADOPTED, 1927; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications cover asphalt roofing in sheet form surfaced on the weather side with fine mineral granules, either 36 or 32 in. in width, composed of roofing felt saturated and coated on both sides with asphalt.

Manufacture

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant then coated on both sides with a hot asphalt coating compounded with a fine mineral filler substantially insoluble in water, and finally surfaced on the weather side with fine granules of talc or other mineral material, and of a color as may be mutually agreed upon between the purchaser and seller, embedded in the hot asphaltic coating. The reverse side shall be covered with powdered talc or mica to prevent the roofing from sticking together in the package.

Character of Felt

3. The felt shall be composed of a continuous sheet of "felted" vegetable and animal fibers. Its surface shall be uniformly smooth and free from lumps of unbeaten stock and particles of hard foreign substances.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of the former Standard Specifications for Asphalt Roll-Roofing Surfaced with Granular Talc (A.S.T.M. Designation: D 248 – 27), which standard was accordingly discontinued in 1933.

Character of Saturant and Coatings

4. The saturant and coatings shall be composed principally of asphaltic materials.

Physical Properties

5. The fabricated product shall conform to the following requirements:

(*a*) *Width.*—The roofing shall be put up in rolls and shall be either 36 or 32 in. in width, as may be specified, within a permissible variation of ±¼ in.

(*b*) *Area.*—The average area of the rolls examined shall contain not less than 108 or 216 sq. ft., as specified, which shall be sufficient to cover 100 or 200 sq. ft., respectively, of roof surface.

	GRADES			
	65 LB.		55 LB.	
	MAX., LB.	MIN., LB.	MAX., LB.	MIN., LB.
(*c*) Weight per roll, net avg. per 108 sq. ft.	....	62.0	....	52.0
(*d*) Weight of dry felt per 108 sq. ft.	....	13.5	....	10.8
(*e*) Weight of saturant (soluble in CS_2) per 108 sq. ft.[a]	....	21.6	....	17.5
(*f*) Weight of weather side coating (soluble in CS_2) per 108 sq. ft.	15.0	8.0	15.0	8.0
(*g*) Weight of reverse side coating (soluble in CS_2) per 108 sq. ft.	....	2.0	....	2.0
(*h*) Weight of mineral matter per 108 sq. ft.:				
Passing No. 14 and retained on No. 100 sieve	17.0	3.0	12.0	3.0
Passing No. 100 sieve	10.0	4.0	10.0	4.0
(*i*) Weight of any 108 sq. ft. roll of complete roofing in the shipment	....	60.0	....	50.0
(*j*) Pliability at 77 F. (25 C.)	at least 8 strips out of 10 shall not crack when bent 90 deg. at a uniform speed over a rounded corner of ½-in. radius.			
(*k*) Behavior on heating to 176 F. (80 C.) for 2 hr	not more than 1.5 per cent volatile matter loss. There shall be no flowing, sagging, blistering, or absorption of the asphalt coatings.			

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[a] The weight of saturant per 108 sq. ft. shall be not less than 1.6 times the weight of the dry felt

Surface Finish

6. The surface shall be smooth or finely veined in appearance. Deeply ribbed surfaces shall be rejected.

Distribution of Coating and Surfacing

7. The coating and surfacing shall be applied uniformly and of approximately equal thickness on both sides and up to the edges of the sheet.

Freedom from Defects

8. The finished product shall be free from visible external defects, such as holes, ragged or untrue edges, rents, cracks, tears, protuberances and indentations.

Pliability and Stickiness

9. The finished product shall not crack or be so sticky as to cause tearing or material damage, upon being unrolled at atmospheric temperatures above 50 F. (10 C.).

Packing

10. (*a*) The roofing shall be put up in rolls of either 108 or 216 sq. ft. No roll shall contain more than two pieces nor shall there be more than 3 per cent of the rolls containing two pieces in any shipment. The rolls shall be tightly wound and securely wrapped in a substantial grade of paper completely encircling the roll, and pasted at the overlap in such a manner as to prevent shifting from position. The ends of the rolls shall be protected with cloth covers or by other suitable means. The nails and lap-cement shall be packed in the core of each roll or furnished separately if so specified by the purchaser.

(*b*) Each roll shall be plainly marked with the manufacturer's name and brand. Special packing shall be as agreed upon between the purchaser and seller.

Nails and Lap-Cement

11. (*a*) *Nails.*—The gage of the wire shall not be greater than Washburn & Moen No. 10 (0.135 in.) nor thinner than No. 12 (0.105 in.); the head shall not be less than $\frac{3}{8}$ in. in diameter, and not less than 0.025 in. in thickness; the shank shall be between $\frac{3}{4}$ and 1 in. in length, with its lower end pointed, and shall be either smooth or barbed, and if the latter, then the barbings shall not increase the diameter of the lower two-thirds more than 0.01 in. The nails shall be zinc coated with not less than $\frac{1}{2}$ oz. nor more than $1\frac{1}{4}$ oz. per sq. ft. of nail surface. Hot-galvanized, electrogalvanized, or sherardized coatings will be accepted. There shall be furnished per "square" not less than an average of 252 nails for 36-in. roofing, and not less than an average of 275 nails for 32-in. roofing.

(*b*) *Lap-Cement.*—The cement shall be composed of bituminous materials dissolved in a volatile solvent, and shall be of such a nature as to firmly bind the laps without injurious effect upon the roofing. The cement shall have a minimum flash point of 71 F. (21.5 C.) when tested by the Tag Closed-Cup Tester. There shall be furnished for each "square" of 36-in. roofing not less than $\frac{3}{4}$ pt. of cement and for 32-in. roofing not less than 1 pt. of cement. The addition of 5 to 20 per cent by weight of short-fibered asbestos shall be permitted, in which case the quantity of cement shall be increased by $\frac{1}{4}$ pt. per "square."

(*c*) *Special Fixtures.*—Special fixtures may be furnished in lieu of nails and cement, if agreed upon by the purchaser and seller.

Sampling and Testing

12. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules; also Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 228 - 33 T) of the American Society for Testing Materials.[1]

Inspection

13. Inspection of material shall be made as mutually agreed upon by the purchaser and seller as part of the purchase contract.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 799 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 941.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT ROOFING SURFACED WITH POWDERED TALC OR MICA[1]

A.S.T.M. Designation: D 224 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1925; ADOPTED IN AMENDED FORM, 1927; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications cover asphalt roofing in sheet form surfaced with finely powdered mineral matter, either 36 or 32 in. in width, composed of roofing felt saturated and coated on both sides with asphalt.

Manufacture

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant then coated on both sides with a hot asphaltic coating compounded with a finely powdered mineral filler, substantially insoluble in water, and finally surfaced on both sides with powdered talc or mica to prevent the roofing from sticking together in the package.

Character of Felt

3. The felt shall be composed of a continuous sheet of "felted" vegetable and animal fibers. Its surface shall be uniformly smooth and free from lumps of unbeaten stock and particles of hard foreign substances.

Character of Saturant and Coatings

4. The saturant and coatings shall be composed principally of asphaltic materials.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of the former Standard Specifications for Asphalt Roll-Roofing Surfaced with Powdered Talc (A.S.T.M. Designation: D 224 - 27), which standard was accordingly discontinued in 1933.

Physical Properties

5. The fabricated product shall conform to the following requirements:

(*a*) *Width.*—The roofing shall be put up in rolls and shall be either 36 or 32 in. in width, as may be specified, within a permissible variation of ±¼ in.

(*b*) *Area.*—The average area of the rolls examined shall contain not less than 108 or 216 sq. ft., as specified, which shall be sufficient to cover 100 or 200 sq. ft., respectively, of roof surface.

	GRADES			
	65 LB.		55 LB.	
	MAX., LB.	MIN., LB.	MAX., LB.	MIN., LB.
(*c*) Weight per roll, net avg. per 108 sq. ft.	....	62.0	....	52.0
(*d*) Weight of dry felt per 108 sq. ft.	....	13.5	....	10.8
(*e*) Weight of saturant (soluble in CS_2) per 108 sq. ft.[a]	....	21.6	....	17.3
(*f*) Weight of coating (soluble in CS_2) per 108 sq. ft.	20.0	15.0	20.0	15.0
(*g*) Weight of mineral matter per 108 sq. ft. passing a No. 100 sieve	8.0	4.0	8.0	4.0
(*h*) Weight of any 108 sq. ft. roll of complete roofing in the shipment	....	60.0	....	50.0
(*i*) Pliability at 77 F. (25 C.)	at least 8 strips out of 10 shall not crack when bent 90 deg. at a uniform speed over a rounded corner of ½-in. radius.			
(*j*) Behavior on heating to 176 F. (80 C.) for 2 hr	not more than 1.5 per cent volatile matter loss. There shall be no flowing, sagging, blistering or absorption of the asphalt coatings.			

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[a] The weight of saturant per 108 sq. ft. shall be not less than 1.6 times the weight of the dry felt.

Surface Finish

6. The surface shall be smooth or finely veined in appearance. Deeply ribbed surfaces shall be rejected.

Distribution of Coating and Surfacing

7. The coating and surfacing shall be applied uniformly and of approximately equal thickness on both sides and up to the edges of the sheet.

Freedom from Defects

8. The finished product shall be free from visible external defects, such as holes, ragged or untrue edges, rents, cracks, tears, protuberances and indentations.

Pliability and Stickiness

9. The finished product shall not crack or be so sticky as to cause tearing or material damage, upon being unrolled at atmospheric temperatures above 50 F. (10 C.).

Packing

10. (*a*) The roofing shall be put up in rolls of either 108 or 216 sq. ft. No roll shall contain more than two pieces nor shall there be more than 3 per cent of the rolls containing two pieces in any shipment. The rolls shall be tightly wound and securely wrapped in a substantial grade of paper completely encircling the roll, and pasted at the overlap in such a manner as to prevent shifting from position. The ends of the rolls shall be protected with cloth covers or by other suitable means. The nails and lap-cement shall be packed in the core of each roll or furnished separately if so specified by the purchaser.

(*b*) Each roll shall be plainly marked with the manufacturer's name and brand. Special packing shall be as agreed upon between the purchaser and seller.

Nails and Lap-Cement

11. (*a*) *Nails.*—The gage of the wire shall not be greater than Washburn & Moen No. 10 (0.135 in.) nor thinner than No. 12 (0.105 in.); the head shall not be less than $\frac{3}{8}$ in. in diameter, and not less than 0.025 in. in thickness; the shank shall be between $\frac{3}{4}$ and 1 in. in length, with its lower end pointed, and shall be either smooth or barbed, and if the latter, then the barbings shall not increase the diameter of the lower two-thirds more than 0.01 in. The nails shall be zinc coated with not less than $\frac{1}{2}$ oz. nor more than $1\frac{1}{4}$ oz. per sq. ft. of nail surface. Hot-galvanized, electrogalvanized, or sherardized coatings will be accepted. There shall be furnished per "square" not less than an average of 252 nails for 36-in. roofing and not less than an average of 275 nails for 32-in. roofing.

(*b*) *Lap-Cement.*—The cement shall be composed of bituminous materials dissolved in a volatile solvent, and shall be of such a nature as to firmly bind the laps without injurious effect upon the roofing. The cement shall have a minimum flash point of 71 F. (21.5 C.) when tested by the Tag Closed-Cup Tester. There shall be furnished for each "square" of 36-in. roofing not less than $\frac{3}{4}$ pt. of cement and for 32-in. roofing not less than 1 pt. of cement. The addition of 5 to 20 per cent by weight of short-fibered asbestos shall be permitted, in which case the quantity of cement shall be increased by $\frac{1}{4}$ pt. per "square."

(*c*) *Special Fixtures.*—Special fixtures may be furnished in lieu of nails and cement, if agreed upon by the purchaser and seller.

Sampling and Testing

12. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the

Tentative Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules; also Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 228 – 33 T) of the American Society for Testing Materials.[1]

Inspection

13. Inspection of material shall be made as mutually agreed upon by the purchaser and seller as part of the purchase contract.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 799 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 941.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT SHINGLES SURFACED WITH COARSE MINERAL GRANULES[1]

A.S.T.M. Designation: D 225 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1925; ADOPTED IN AMENDED FORM, 1927; REVISED, 1929; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.

Scope

1. These specifications cover asphalt roofing in shingle form surfaced with colored mineral granules, composed of roofing felt saturated and coated on both sides with asphalt and surfaced on the weather side with granulated slate or equivalent mineral material (of solid or mixed colors as may be mutually agreed upon between the purchaser and seller), and on the reverse side with powdered talc or mica. Such roofing is intended for use as a roof covering for buildings.

Manufacture

2. In the process of manufacture, a single thickness of dry roofing felt shall be impregnated with a hot asphaltic saturant, then coated on both sides with a hot asphaltic coating compounded with a fine mineral filler substantially insoluble in water, and finally surfaced on the weather side with mineral granules embedded in the hot asphaltic coating. The reverse side shall be covered with powdered talc or mica to prevent the roofing from sticking together in the package.

Character of Felt

3. The felt shall be composed of a continuous sheet of "felted" vegetable and animal fibers. Its surface shall be uniformly smooth and free from lumps of unbeaten stock and particles of hard foreign substances.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

These specifications are in effect a revision of the former Standard Specifications for Asphalt Roll-Roofing and Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 225 - 29), which standard was accordingly discontinued in 1933.

Character of Saturant and Coatings

4. The saturant and coatings shall be composed principally of asphaltic materials.

Physical Properties

5. The fabricated product shall conform to the following requirements:

(*a*) *Shape.*—The form and size of the shingles shall be as agreed upon between the purchaser and seller.

(*b*) *Area.*—Sufficient material per "square" shall be furnished to adequately waterproof 100 sq. ft. of roof surface.

	GRADES			
	HEAVY WEIGHT		REGULAR WEIGHT	
	MAX., LB.	MIN., LB.	MAX., LB.	MIN., LB.
(*c*) Weight, net avg. per 108 sq. ft.	....	102.0	....	86.0
(*d*) Weight of dry felt per 108 sq. ft.	....	15.7	....	10.8
(*e*) Weight of saturant per 108 sq. ft.[a]	....	27.5	....	18.9
(*f*) Weight of weather side coating (soluble in CS_2) per 108 sq. ft.	20.0	12.0	20.0	12.0
(*g*) Weight of reverse side coating (soluble in CS_2) per 108 sq. ft.	5.0	2.0	5.0	2.0
(*h*) Weight of mineral matter per 108 sq. ft. passing No. 6 and retained on No. 100 sieve	40.0	25.0	40.0	25.0
(*i*) Weight of mineral matter per 108 sq. ft. passing No. 100 sieve	10.0	4.0	10.0	4.0
(*j*) Weight of complete roofing per 108 sq. ft.	....	97.0	....	83.0
(*k*) Behavior on heating to 176 F. (80 C.) for 2 hr.	not more than 1.5 per cent volatile matter loss. The granular surfacing shall not slide more than $\frac{1}{16}$ in. when suspended vertically.			

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[a] The weight of saturant per 108 sq. ft. shall be not less than 1.75 times the weight of the dry felt.

Surface Finish

6. (*a*) The weather surface shall be uniform in finish and texture. The mineral granules shall be uniformly distributed over the entire surface and so firmly embedded in the asphalt coating that when rubbed vigorously with the hand, sufficient will remain to completely cover the coating.

(*b*) The reverse side shall have a substantial coating of asphalt applied uniformly to the edges and be surfaced with powdered talc or mica.

Saturation

7. The felt shall be completely and uniformly saturated and shall show no unsaturated spots at any point when the roofing is cut or split open.

Freedom from Defects

8. The finished shingles shall be free from visible external defects such as holes, ragged or untrue edges, rents, cracks, indentations or lumps of coating. The shingles shall not stick together in the packages so as to cause damage upon being unpacked at atmospheric temperatures above 50 F. (10 C).

Packing

9. (*a*) The shingles shall be put up in bundles weighing not more than 135 lb., gross. They shall be packed in cardboard cartons or between wood or cardboard ends and tied with wire or metal bands so as to make a substantial package, as may be agreed upon by the purchaser and seller.

(*b*) Each package shall be plainly marked with the manufacturer's name and brand and shall contain printed directions for laying.

Sampling and Testing

10. The material shall be sampled and the properties enumerated in these specifications shall be determined in accordance with the Tentative Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc or Mineral Granules; also Asphalt Shingles Surfaced with Mineral Granules (A.S.T.M. Designation: D 228 – 33 T) of the American Society for Testing Materials.[1]

Inspection

11. Inspection of material shall be made as mutually agreed upon by the purchaser and seller as part of the purchase contract.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 799 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 941.

TENTATIVE METHOD OF TEST
FOR
COARSE PARTICLES IN MIXTURES OF ASPHALT AND MINERAL MATTER[1]

A.S.T.M. Designation: D 313 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1929; REVISED, 1935.

Scope

1. This method covers the determination of the amount of particles of mineral or other insoluble matter in asphaltic mixtures that are retained upon a No. 200 (74-micron) A.S.T.M. sieve.

Sampling

2. The material shall be sampled in accordance with the Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140) of the American Society for Testing Materials.[2]

Treatment of Sample

3. The sample as received shall be completely melted in an oven at the lowest possible temperature and while cooling shall be stirred until it reaches room temperature in order to insure homogeneity.

Apparatus

4. (*a*) The apparatus shall consist of a 3-in. No. 200 (74-micron) sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3]

(*b*) A 3-in. No. 200 (74-micron) sieve for comparison purposes shall be retained in the laboratory as a standard. Whenever a new sieve is secured, a practical test of its accuracy should be made by running on it, and on the standard sieve, a comparison test, using powdered mineral matter that has a considerable percentage of coarse particles. A reserve stock of such powdered mineral filler should be kept for this purpose.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-8 on Bituminous Waterproofing and Roofing Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 974.

[3] *Ibid.*, p. 1244.

Procedure

5. (*a*) The sieve shall be dried in an oven at 105 to 110 C., cooled, and then weighed on an analytical balance, the weight being recorded to the nearest 1 mg.

(*b*) A sample of the asphalt sufficient to yield about 1 g. of mineral matter shall be weighed into a 400-ml. beaker. Then carbon disulfide, carbon tetrachloride or benzol shall be added and the mixture warmed until the asphalt is entirely dissolved. The solution obtained shall be poured through the weighed sieve, and the residue in the beaker shall be washed onto the sieve, using the solvent employed.

(*c*) The sieve containing the residue shall be washed with the solvent employed, using a camel's hair brush, until free from asphalt and fine mineral matter, then dried and weighed. During the washing, the residue in the sieve shall be covered with the solvent to a depth of approximately $\frac{1}{2}$ in.

Percentage of Coarse Particles

6. From the weight of the sample taken, the percentage of ash and the weight of the residue retained on the sieve, the percentage of coarse particles in the mineral matter shall be calculated.

TENTATIVE SPECIFICATIONS
FOR
FLEXIBLE VARNISHED TUBING USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 372 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1935.

Scope

1. These specifications cover three grades of flexible varnished tubing which are used as electrical insulation for leads on electrical apparatus, as follows:

Grade A.—Tubing generally known as "flexible varnished tubing," or "motor and transformer tubing," or "impregnated magneto tubing;"

Grade B.—Tubing generally known as "radio spaghetti;" and

Grade C.—Tubing generally known as "non-flammable tubing," or "flame-resistant tubing."

NOTE.—The term "varnished tubing" as used in these specifications refers to braided cotton sleeving coated or impregnated and coated with lacquer or a combination of lacquer and varnish or other similar coatings.

Material

2. (*a*) The base material of the tubing shall be good quality braided cotton sleeving.

(*b*) The cotton sleeving shall be uniformly treated, and the finished tubing shall be reasonably free from defects such as pimples, blisters, wrinkles, cracks, and similar imperfections.

Color

3. The color desired shall be specified by the purchaser.

Dimensions

4. The inside diameters of flexible varnished tubing shall conform to the following requirements:

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

SIZE	INSIDE DIAMETER, IN.			SIZE	INSIDE DIAMETER, IN.		
	MAXIMUM	MINIMUM	NOMINAL		MAXIMUM	MINIMUM	NOMINAL
1........	0.299	0.289	0.294	10.......	0.110	0.102	0.106
2........	0.268	0.258	0.263	11.......	0.099	0.091	0.095
3........	0.239	0.229	0.234	12.......	0.089	0.081	0.085
4........	0.212	0.204	0.208	13.......	0.080	0.072	0.076
5........	0.190	0.182	0.186	14.......	0.068	0.064	0.066
6........	0.170	0.162	0.166	15.......	0.061	0.057	0.059
7........	0.152	0.144	0.148	16.......	0.055	0.051	0.053
8........	0.137	0.129	0.133	17.......	0.049	0.045	0.047
9........	0.122	0.114	0.118	18.......	0.044	0.040	0.042

NOTE.—For the millimeter sizes of foreign-made tubing and for odd sizes not contained in the above table, the nominal inside diameter shall be 0.004 in. (0.1016 mm.) larger than the diameter it is intended to cover for all sizes between the limits of 0.076 in. (1.93 mm.) and 0.208 in. (5.28 mm.) and shall be subject to a permissible variation of ±0.004 in. (0.1016 mm.). For sizes larger than 0.208 in. (5.28 mm.), the nominal inside diameter shall be 0.005 in. (0.127 mm.) larger than the diameter it is intended to cover and shall be subject to a permissible variation of ±0.005 in. (0.127 mm.). For sizes smaller than 0.076 in. (1.93 mm.), the nominal inside diameter shall be 0.002 in. (0.0508 mm.) larger than the diameter it is intended to cover and shall be subject to a permissible variation of ±0.002 in. (0.0508 mm.).

Dielectric Strength

5. (*a*) Grade A tubing shall show an average value in the short-time dielectric strength test of not less than 7000 v., and no one of the ten puncturing voltages shall be less than 5000 v.

(*b*) Grade B tubing shall show an average value in the short-time dielectric strength test of not less than 4000 v., and no one of the ten puncturing voltages shall be less than 2500 v.

(*c*) Grade C tubing shall show an average value in the short-time dielectric strength test of not less than 2500 v., and no one of the ten puncturing voltages shall be less than 1500 v.

Heat Endurance

6. The number of hours of baking in the heat endurance test at which first cracking of the tubing occurs when bent through 180 deg. over a rod 0.32 cm. ($\frac{1}{8}$ in.) in diameter shall be not less than the following:

Grade A...	96 hr.
Grade B...	72 hr.
Grade C...	48 hr.

Rate of Burning

7. Tubing furnished under these specifications as Grade C shall require at least 45 sec. to burn a length of 2.54 cm. (1 in.).

Commercial Lengths

8. The tubing shall be supplied in straight lengths of 30 or 36 in. or in continuous lengths as may be specified by the purchaser.

Packing

9. Unless otherwise specified by the purchaser, the tubing shall be packed flat in packages conforming to usual trade customs.

Marking

10. Each package shall be marked with the name or trade mark of the manufacturer, the total number of feet, the size and color of the tubing.

Inspection

11. The tubing shall be inspected and tested within two weeks of the date of receipt by the purchaser.

Rejection

12. If the results of any test do not conform to the requirements prescribed in these specifications, that test shall be repeated on two additional specimens from the same lot, each of which shall conform to the requirements specified. If either of these two additional specimens fails, the lot of tubing represented by that specimen may be rejected at the option of the purchaser.

Rehearing

13. Samples of rejected material shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of test, the manufacturer may make claim for a rehearing within that time.

Methods of Testing

14. Flexible varnished tubing shall be sampled, conditioned, and tested in accordance with the Tentative Methods of Testing Flexible Varnished Tubing Used for Electrical Insulation (A.S.T.M. Designation: D 350 – 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 1080.

TENTATIVE METHODS OF TESTING SOLID FILLING AND TREATING COMPOUNDS USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 176 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1923; REVISED, 1924, 1925, 1929, 1933, 1934, 1935.

Scope

1. These methods cover physical and electrical tests for solid filling and treating compounds for electrical insulation.

NOTE.—Before testing under these methods it may be necessary to degasify (*a*) materials which tend to entrap gases (usually due to high viscosity) and/or (*b*) materials which tend to froth on heating. (See Appendix I.).

PHYSICAL TESTS

General Physical Tests

2. Each of the following tests shall be made in accordance with the method of test applicable, of the American Society for Testing Materials, as indicated:

(*a*) *Melting Point:* Standard Method of Test for Melting Point of Petrolatum (A.S.T.M. Designation: D 127).[2]

(*b*) *Softening Point,* for compounds having no definite melting point: Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (A.S.T.M. Designation: D 36),[3] or Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (A.S.T.M. Designation: D 61).[4] The method used should be indicated in the report.

(*c*) *Flash and Fire Points:* Standard Method of Test for Flash and Fire Points by Means of Open Cup (A.S.T.M. Designation: D 92).[5]

(*d*) *Evaporation:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (A.S.T.M. Designation: D 6).[6]

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 840.

[3] *Ibid.*, p. 984.

[4] *Ibid.*, p. 989.

[5] *Ibid.*, p. 800.

[6] *Ibid.*, p. 962.

(*e*) *Viscosity*, Temperature range from melting point to 150 C.: Saybolt Furol, Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88).[1]

(*f*) *Penetration Test*, Temperature range from melting or softening point to −25 C.: Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5).[2]

Brittleness

3. To determine the brittleness of the material, the compound shall be spread on a piece of sheet metal in a layer $\frac{1}{16}$ in. in thickness. It shall then be submerged in water having a temperature at least 20 F. above the expected breaking point. It shall then be cooled 5 F. and held at this temperature for 5 minutes. The cooling shall then be continued in increments of 5 F. At each temperature interval the compounds shall be tested with the blade of a knife, inserting the point with the blade as nearly parallel with the sheet metal as is practicable, and pulling the compound from the sheet metal as rapidly as possible by rotating the blade about its back as an axis. The temperature at which the compound no longer stretches but snaps, shall be considered the breaking point.

SPECIFIC GRAVITY

Scope

4. This test is intended to determine the specific gravity of both untreated and degasified compounds at any temperature. The approximate volume occupied by entrapped gas at any temperature can be calculated from the difference in specific gravity of an untreated and a degasified sample at that same temperature.

Procedure

5. (*a*) The specific gravity shall be determined by the Standard Method of Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments (A.S.T.M. Designation: D 71)[3] or by the Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (A.S.T.M. Designation: D 70)[4] of the American Society for Testing Materials.

(*b*) If degasification is required, it shall be performed as described in Section 11 and Appendix I.

Volume of Entrapped Gases

6. The percentage of entrapped gases may be calculated from the following formula:

$$\text{Volume, in per cent, of entrapped gases} = \frac{\text{sp. gr. of degasified compound} - \text{sp. gr. of untreated compound}}{\text{sp. gr. of degasified compound}} \times 100$$

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 880.

[2] *Ibid.*, p. 971.

[3] *Ibid.*, p. 1000.

[4] *Ibid.*, p. 1002.

COEFFICIENT OF EXPANSION

NOTE.—Certain materials when cooled form voids within the mass and no satisfactory method has been found to measure their coefficient of expansion.

Scope

7. These methods are intended for determining the true and effective coefficient of expansion of compounds. The true coefficient of expansion is for compounds which are free of entrapped gases. The effective coefficient of expansion is the coefficient for material which has not been degasified just prior to test. It is important for many purposes to know the effective coefficient of the material as received or after heating to the maximum temperature of application. Consistent results, however, may only be obtained with gas-free compounds.

Methods

8. The following methods are covered:

Methods A and B.—Methods *A* and *B* for true coefficient of expansion are intended for use only where the uniformity of the material under test justifies a high degree of precision. Method *A* is suitable for testing low-viscosity types such as waxes and petrolatums. Method *B* is suitable for testing asphalts and high-viscosity materials, also for opaque materials which may give difficulty in reading the glass scale of Method *A*.

Methods C, D and E.—Methods *C*, *D* and *E* are intended for faster testing where high precision may not be justified. These methods may be used for determining either true or effective coefficient of expansion.

Method A. Using Glass Flask

Apparatus

9. (*a*) *Flask.*—The flask[1] shall hold approximately 250 ml. to the zero mark, and the neck of the flask shall be 1 cm. in internal diameter and graduated for 25 ml. in 0.1-ml. divisions.

(*b*) *Oil Bath.*—The cylindrical oil bath for heating the sample shall be approximately 10 in. (25.4 cm.) in inside diameter and 20 in. (50.8 cm.) in inside depth with a false bottom 1 in. from the bottom and shall have provision for circulating and heating the oil.

(*c*) *Lead Collar.*—A lead collar shall be hung on the flask during test to prevent the oil currents of the bath from moving the flask.

Calibration

10. The capacity of the flask at the zero point and several points on the scale shall be determined by filling the flask with distilled water at a known temperature and weighing.

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[1] A Pyrex or quartz glass flask is very satisfactory for this purpose.

Procedure

11. (*a*) The flask shall be maintained under a vacuum of 25 in. of mercury and a temperature 50 C. higher than the softening point (ring-and-ball method, as determined under Section 2 (*b*)) while being filled and for approximately 30 min. after filling is complete. The flask shall be filled to within the last milliliter marked on the neck when held at the maximum test temperature and slowly cooled to room temperature (10 to 12 hr.). Before starting the test, the flask shall be examined for the presence of cavities or irregular contraction of the compound. Some compounds after cooling below the liquid state, tend to stick to the sides of the neck of the flask. In such cases it is necessary to gradually warm the neck and flow the compound to meet the rest, after which the flask shall be placed in the bath for several hours to insure temperature equilibrium.

(*b*) With the compound satisfactorily placed in the flask at the lowest temperature, the height of the column in the neck shall be read and the bath then slowly heated. Readings shall be taken at 50 C. intervals, holding the bath as constant as possible at each point until no more expansion occurs at that point, the procedure being repeated for each point until maximum temperature is reached.

(*c*) *Precautions.*—During the test, temperature readings shall be taken at top and bottom of the bath to detect any variation. Readings of the expansion of the compound shall be made at intervals long enough to insure uniform temperature distribution and complete movement of the compound. Until complete liquefaction, the interval should be 3 to 4 hr.; after liquefaction it may be reduced to 30 min.

Calculation

12. (*a*) After securing the readings over the temperature range desired, a curve shall be plotted from the temperature and expansion readings from which the coefficient of expansion shall be calculated from the following formula:

$$\text{Coefficient of expansion of the compound} = \frac{V_1 - V}{(T_1 - T)\,V} + C$$

where V = the original volume occupied by the compound;

V_1 = the volume at higher temperature occupied by the compound;

T = the original temperature;

T_1 = the higher temperature, and

C = a constant = coefficient of expansion of glass container.

(*b*) The coefficient of expansion shall be calculated for three temperature ranges, as follows:

(*1*) From the minimum temperature at which the measurement was made to 10 C. below the melting point. This is intended to give the average coefficient for the solid condition.

(*2*) From 5 C. above the melting point to 100 C. This is intended to give the average coefficient for the liquid condition.

(*3*) From the minimum temperature at which a measurement was made to 100 C.

Method B. Using Metallic Cell

Apparatus

13. (*a*) *Metal Cell.*—The cell shall be made of steel, consisting of four parts, a cylinder about 2.5 in. in internal diameter, having a rigid bottom, a metallic gasket, a cover to which a steel capillary tube is attached and an auxiliary cover for introducing the compound to be tested while the cell is under a vacuum. The cell shall have an internal volume of approximately 250 ml. A metallic cell that has been found suitable is described in Appendix II.

(*b*) *Oil Bath.*—The oil bath shall be the same as described in Section 9 (*b*), Method *A*, with the exception that provision shall be made for supporting the metal cell.

Calibration

14. The cell shall be calibrated to determine its volume at various temperatures as follows:

(*a*) Weigh the assembled cell to determine its tare weight.

(*b*) Fill the cell with mercury until replacing the cover causes some to extrude through the capillary tubing. Record the weight of the cell and mercury and note the temperature.

(*c*) Place cell in the oil bath in an inverted position. The capillary tubing should extend over the side of the oil bath in such a way that the extruded mercury may be caught in a beaker. The oil bath which is several degrees above room temperature causes some mercury to be extruded from the capillary tube. When all expansion has taken place, weigh the mercury collected.

(*d*) Adjust the oil bath for other test temperatures and note the amounts of mercury extruded. The weight of mercury in the cell at any temperature is thus determined and the volume may be calculated.

Procedure

15. (*a*) The cell shall be fitted with the auxiliary cover and held in an upright position in the oil bath while filling. A vacuum of 25 in.

of mercury and a temperature 50 C. higher than the softening point (ring-and-ball method, as determined under Section 2 (*b*)) shall be maintained while filling and for at least 30 min. after the cell has been filled to within approximately $\frac{1}{4}$ in. of the cover. The cell shall then be slowly cooled to room temperature, and any irregularities in the surface of the compound removed.

(*b*) The auxiliary cover shall be replaced with the standard cover and the cell and compound weighed.

(*c*) Sufficient mercury shall be poured into the cell so that some is extruded when the cover is screwed down. The cell shall then be weighed again.

(*d*) The cell shall then be inverted and placed in the oil bath, and the procedure outlined under calibration, Section 14 (*c*) and (*d*) again followed for 5 C. intervals.

(*e*) *Precautions.*—Only clean, distilled mercury shall be used. During the test, temperature readings shall be taken at top and bottom of the bath to detect any variation. Readings of the expansion of the compound should be made at intervals long enough to insure uniform temperature distribution and complete movement of the compound. Until complete liquefaction, the interval should be 3 to 4 hr.; after liquefaction, it may be reduced to 30 min.

Calculation

16. (*a*) After volumetric determinations have been made over the desired temperature range, a curve shall be plotted between volume and temperature readings from which the coefficient of expansion shall be calculated from the following formula:

$$\text{Coefficient of expansion of the compound} = \frac{V_1 - V}{(T_1 - T)\,V}$$

where V = the original volume occupied by the compound;
V_1 = the volume at higher temperature occupied by the compound;
T = the original temperature, and
T_1 = the final temperature.

(*b*) The coefficient of expansion shall be calculated for the same three ranges as prescribed in Method *A*, Section 12 (*b*).

Report

17. The report shall include the following:

(*a*) The type of cell used.

(*b*) A copy of the volume-temperature curve.

(*c*) The temperature ranges as defined under Section 12 (*b*) or 16 (*b*).

(*d*) The coefficient of expansion corresponding to each of the three temperature ranges.

Method C. Specific Gravity Method

Procedure

18. The specific gravity of untreated or degasified compound at two test temperatures may be found by either of the procedures specified in Section 5.

Calculation

19. From the temperature and specific gravity readings the coefficient of expansion shall be calculated from the following formula:

$$\text{Coefficient of expansion} = \frac{\text{sp. gr. at } T - \text{sp. gr. at } T_1}{(T_1 - T)\ \text{sp. gr. at } T_1}$$

where T = the initial temperature, and
T_1 = the higher temperature.

Method D. Pycnometer Contraction

Scope

20. This method is a modification of the specific gravity method (Method *C*). It may be applied to either untreated or degasified compounds.

Apparatus

21. (*a*) *Flask.*—A 100-ml. volumetric glass[1] flask shall be used and the zero mark shall be as near as possible to the bulb of the flask.

(*b*) *Oil Bath.*—The oil bath may consist of a tall-form glass[1] beaker of sufficient size so that when the flask is supported about 1 in. from the bottom the oil level will reach at least to the zero mark of the flask.

(*c*) *Metal Collar.*—Lead or iron collars placed on the neck of the flask shall be used during heating to prevent oil currents of the bath from moving the flask.

Procedure

22. (*a*) The flask shall be weighed and then filled to within approximately 10 ml. of the zero mark with the compound to be tested, care being taken that at no time shall the temperature of the compound exceed the softening point (ring-and-ball method) by more than 10 C. Care shall also be taken so that none of the compound remains in the stem of the flask. The flask shall be cooled to room temperature, weighed, immersed in the oil bath and placed in an oven previously heated to the maximum temperature at which the test is to be run. After the oil bath reaches the test temperature it shall be allowed to remain at this temperature for 1 hr. The flask shall be removed from the oven, and mercury from a burette shall be quickly poured into it until the level of the compound is within 0.5 ml. of the zero mark. The quantity of mercury used shall be noted in mil-

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[1] Pyrex glass or other material with equally low coefficient of expansion is very satisfactory for this purpose.

liliters. The flask shall be replaced in the oven for 20 min., removed again and the mercury titration shall be continued until the level of the compound is exactly at the zero mark. The number of milliliters of mercury used in both titrations shall be recorded.

(*b*) The oven temperature shall be reset at the next lower test point, temperature equilibrium allowed for as above, and the titration shall be repeated. The same procedure shall be continued at all subsequent test points, the milliliters of mercury added at each point being recorded.

Calculations

23. To find the coefficient of expansion of the material between any two temperatures, the calculations shall be made as follows:

Volume of mercury A at room temperature corrected to temperature $t = A + 0.000182A\ (t - 20)$

Example.—If volume of flask is 100 ml. at 20 C.; volume at $t = 100 + 0.0025\ (t - 20)$ ml.

Let $X = V_1 - M_1$ = the volume of compound at T_1,

Let $Y = V_2 - M_2$ = the volume of compound at T_2,

Then the expansion in cu. cm. per gram, $T_1 - T_2 = \frac{X}{W} - \frac{Y}{W}$

$$\text{the expansion per cu. cm., } T_1 - T_2 = \frac{\frac{X - Y}{W}}{\frac{Y}{W}} = \frac{X - Y}{Y}$$

$$\text{the coefficient of expansion, cu. cm. per cu. cm. per degree Centigrade} = \frac{X - Y}{Y\ (T_1 - T_2)}$$

where W = the weight of sample in grams

T_1 = the higher temperature in degrees Centigrade

T_2 = the lower temperature in degrees Centigrade

M_1 = milliliters of mercury (corrected) added at T_1

M_2 = the sum of milliliters of mercury (corrected) added at T_1 and at T_2

V_1 = the corrected volume of flask at T_1

V_2 = the corrected volume of flask at T_2

To obtain the curve of expansion, plot the points $\frac{W}{X}$, $\frac{W}{Y}$, etc., which are the densities at various temperatures.

Method E. Pycnometer Expansion

Scope

24. This method is another modification of the specific gravity method (Method *C*) and may also be applied to either untreated or degasified materials.

Apparatus and Calibration

25. The pycnometer and bath required are the same as described in Section 21, except that the neck of the flask shall be cut off at the 100-ml. point and ground square. A metal pycnometer may be used provided its coefficient of expansion is known and is used in Section 27.

Procedure

26. In this procedure the pycnometer shall be allowed to cool slowly to the lowest test temperature. During the cooling period the flask shall be kept filled by adding more compound and after equilibrium is reached the excess material shall be removed by passing a sharp, flat blade over the rim. The flask shall then be removed from the bath and quickly weighed. Knowing the tare weight and volume of the flask, the specific gravity may be determined. For successively higher temperatures, it is only necessary to weigh the extruded portion.

Calculations

27. From the temperature and weight readings the coefficient of expansion may be calculated from the following formula:

$$\text{Coefficient of expansion} = \frac{W - W_1}{W_1 (T_1 - \text{T})} - \frac{WC}{W_1}$$

where W = the initial weight of the compound in the flask
W_1 = the weight of the compound in the flask at higher temperature
T = the initial temperature
T_1 = the higher temperature
C = the coefficient of expansion of the flask

ELECTRICAL TESTS

DIELECTRIC STRENGTH TEST

Dielectric Strength

28. (*a*) This test is intended to determine the dielectric strength of solid filling and treating compounds under voltage stresses of short duration. It is of value as a comparative test but does not indicate the permanent dielectric strength of these compounds.

(*b*) The dielectric strength of this class of material varies with the temperature. It is, therefore, recommended that a sufficient number of tests be made at different temperatures to establish the momentary dielectric strength-temperature curve from 0 to 100 C.

Sample

29. A representative sample shall be taken from the original package, melted and poured directly into the testing container. Care should be exercised in melting and pouring the compound not to over-

heat it nor to entrap air. A melting and pouring temperature of approximately 50 C. above the softening point (ring-and-ball method) as determined under Section 2 (*b*) is recommended. The electrodes shall be heated to the approximate temperature of the compound before filling the container.

Electrodes

30. (*a*) The testing container, after filling, shall be placed in a suitable constant-temperature air bath or oil bath and sufficient time allowed to elapse to bring the entire mass to a uniform temperature. The temperature shall be determined by a thermocouple attached to one of the metal electrode ends or by a mercury thermometer placed vertically touching an electrode and approximately ½ in. (1.25 cm.) from the gap between electrodes.

(*b*) The test shall be made between polished hemispherical (Note 1) brass or copper electrodes ½ in. in diameter separated by a gap of 0.1 in. (Note 2).

NOTE 1.—A convenient form of apparatus for holding the electrodes and compound is described in Appendix III. It is recognized that when liquid materials are being tested, this method is inconsistent with the Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117) of the American Society for Testing Materials.[1] However, since spherical electrodes are considered preferable for solid and semisolid materials, the advantage of using spherical electrodes for all splicing compounds, whether liquid or solid, so that direct comparison can be made, is sufficiently great to justify the inconsistency with Methods D 117.

NOTE 2.—In the case of materials which cannot be broken down with the available voltage, the gap may be reduced to 0.05 in. but results will not be comparable directly with those obtained with the 0.1-in. gap.

Testing Transformer Voltage Control and Measurement

31. (*a*) The testing transformer used, methods of voltage control and measurement shall be as outlined in Section 2 of the Tentative Methods of Testing Sheet, Tape and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 – 34 T) of the American Society for Testing Materials.[2]

(*b*) The actual gap at the test temperature shall be determined by direct measurement or by measurement at some other temperature and computation of changes due to expansion or contraction.

(*c*) Voltage shall be applied at a value less than 1000 v. and raised at the rate of 1000 v. per sec. until breakdown occurs.

Number of Specimens

32. Five specimens at a given temperature shall be tested and the average value taken as the momentary dielectric strength of the compound at that temperature.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1087.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 982 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 980.

Report

33. The report shall include the following:

(*a*) The momentary dielectric strength – temperature curve;

(*b*) The individual values of the puncturing voltage and the gap length at the various temperatures.

VOLUME RESISTANCE – TEMPERATURE CHARACTERISTICS

Volume Resistance versus Temperature

34. (*a*) This test is intended to determine the volume resistance – temperature characteristics of solid filling and treating compounds. It is of value as a comparative test and also may be used in determining the volume resistivity on an ohm-centimeter basis.

Temperature Range

(*b*) The volume resistance of this class of material varies with the temperature, generally decreasing rapidly with increase of temperature. It is, therefore, recommended that a sufficient number of tests be made at different temperatures to establish the volume resistance – temperature curve. To be of most significance, the test shall include determinations made up to the highest service temperatures. At room temperatures and below, the volume resistance of practically all of these compounds is so high that it cannot be measured with the ordinary galvanometer equipment.

Conductivity Cell

35. A suitable conductivity cell consisting of parallel planes, concentric cylinders, or coaxial cones shall be used in determining the volume resistance of the compound. The distance between electrodes shall not be less than 0.75 mm. (0.03 in.) nor more than 5 mm. (0.2 in.). The voltage gradient shall not exceed 200 v. per millimeter (5 v. per mil). The area of the electrode shall be sufficiently large so that the current flow can be measured, with the apparatus available, to an accuracy within 5 per cent. Electrode areas of 50 to 500 sq. cm. (7.7 to 77.5 sq in.) should prove suitable. Because of possible catalytic or corrosion effects of some compounds on certain metals, the electrodes should be nickel, gold or platinum plated.

The insulating material used to support the electrodes shall be capable of withstanding the wide temperature range to which the cell is subjected and preferably shall be of an inorganic material such as a ceramic material or suitable glass.

A test run on the empty cell shall be made over the temperature range chosen in order to determine if any leakage is present.

A conductivity cell that has been found suitable is described in Appendix IV.

Sample

36. (*a*) A representative sample shall be taken from the original package, melted and poured directly into the testing container. Care shall be exercised in melting and pouring the compound not to overheat nor to entrap air in it. A melting and pouring temperature of approximately 50 C. above the softening point (ring-and-ball method) as determined under Section 2 (*b*) is recommended. The quantity of the sample depends upon the capacity of the resistivity cell used, but in any case it shall be sufficient to permit three separate determinations. Before filling, the conductivity cell shall be heated to slightly above the pouring temperature of the compound.

(*b*) A suggested procedure in filling the cell, especially in the case of the higher melting compounds, is to determine the quantity of compound necessary to just fill the cell with the electrodes in position. In the case of coaxial cones or concentric cylinders the proper quantity of the heated compound shall be first poured slowly into the outer cylinder. Any bubbles which may form on the surface of the compound shall be removed by a quick application of a flame from a bunsen burner. Immediately the inner electrode shall be slowly lowered into the compound and a thermometer placed in the well.

Test Procedure

37. The conductivity cell, after filling, shall be placed in an oil or air bath having suitable temperature control and sufficient time allowed to elapse to bring the bath and cell to temperature equilibrium at each test temperature. The temperature of the cell shall be determined by two mercury thermometers placed in contact with the electrodes. The temperature of the bath shall be determined by a mercury thermometer placed near the cell. The temperature of the bath shall be within 1 C. of the test temperature when readings are taken. The temperatures of the cell thermometers shall agree within 0.5 C. of each other and within 1 C. of the bath temperature when readings are taken.

Measurements and Calculations

38. The volume resistance shall be measured at each temperature in accordance with the Standard Methods of Test for Resistivity of Insulating Materials (A.S.T.M. Designation: D 257) of the American Society for Testing Materials,[1] with particular attention to Sections 8, 9, 10, 17, 18 and 19 for liquid insulating materials.

Report

39. The report shall include the following:

(*a*) The type of resistivity cell used;

(*b*) The distance between guarded and unguarded electrodes;

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1107.

(*c*) The area of guarded electrode;

(*d*) The battery voltage; and

(*e*) A curve plotted from the readings obtained over the temperature range chosen showing the relation of volume resistance in ohm-centimeter units and the temperature in degrees Centigrade.

NOTE.—In lieu of the information required in Paragraphs (*b*) and (*c*), a statement of the approximate overall accuracy may be made.

POWER FACTOR AND DIELECTRIC CONSTANT

Scope

40. This test is intended to determine the power factor and the dielectric constant of solid filling and treating compounds at specified temperatures corresponding to those temperatures to which the materials are to be subjected in service.

Temperature Range

41. Since the power factor and dielectric constant of this class of materials vary with the temperature, a sufficient number of tests shall be made at different temperatures to establish the dielectric constant - temperature curve and the power factor - temperature curve over the temperature range to which the respective material is subjected in service. Determinations shall be made at not less than three temperatures; a temperature near the lowest to which the material is to be subjected in service, ordinary room temperature of 20 to 25 C., and a temperature near the maximum temperature to which it is subjected in service.

NOTE.—For many materials the power factor - temperature curve may have a maximum, minimum, or other irregularity within the working range of temperatures. With such a material many determinations may be required to establish the curve.

Test Specimens

42. The materials to which these tests apply fall into two classes as regards the most suitable type of specimen to be used in the measurement of power factor and dielectric constant. One class includes waxes and other materials which can be cast or pressed into sheet form and then measured between electrodes, such as are used in making tests on porcelain, molded materials and sheet materials. (See the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 35 T) of the American Society for Testing Materials.[1]) The other class includes materials that are fluid at ordinary temperature or can be made so by increasing their temperatures. Materials in the fluid state can be poured into a measuring cell such as described in Section 34 and the determinations made from which the power factor and the dielectric constant can be calculated.

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[1] See p. 1044.

Measuring Cell

43. In the measuring cell the distance between the electrodes and the area of the electrodes shall be such that a capacitance of not less than 100 $\mu\mu$f. will be obtainable. The voltage gradient shall not be over 5 v. per mil. Due to the catalytic or corrosive effects of some compounds on certain metals, the electrodes may need to be nickel, gold, or platinum plated. The insulating material used to support the electrodes shall be capable of withstanding the wide temperature range to which the cell or material is to be subjected during the tests without any appreciable effect upon the determinations being made. Certain ceramic materials, special glasses, and quartz have been found suitable for insulating supports for the electrodes between which the material is to be measured. One cell that has been found satisfactory for these determinations is described in Appendix IV. Cells of different construction from the one described have been used with equally satisfactory results.

Sampling

44. A representative sample shall be taken from the original package, melted if necessary, and then either cast in the form of a disk or poured directly into the measuring cell. The use of the cell or the disk will depend upon the particular material. In heating and pouring the compound, care shall be exercised not to entrap air in the compound between the electrodes. A melting and pouring temperature of approximately 50 C. above the softening point (ring-and-ball method, as determined under Section 2 (*b*)) is recommended. A sufficient quantity of the material shall be taken as the sample to enable making at least three determinations. Before pouring the compound into the container or cell, the container or cell shall be heated to a temperature slightly higher than the temperature at which the compound is being poured.

Temperature Bath

45. The specimen as prepared above, shall be placed in an oil or air bath having suitable temperature control, and sufficient time allowed to elapse to bring the bath and specimen to the desired temperature equilibrium at each test temperature. The temperature of the electrodes and the compound shall be determined by two mercury thermometers, or two thermocouples with cold junctions placed in contact with the electrodes. The temperature of the bath shall be determined by a thermometer, or a thermocouple with cold junction placed near the cell or the specimen. The temperature of the bath shall be within 1 C. of the desired test temperature when the

determinations are made. The temperature of the specimen thermometers or thermocouples shall agree within 0.5 C. of each other and within 1 C. of the bath temperature when the readings are taken.

Measurements

46. Determinations shall be made of the power factor and dielectric constant at the temperatures and frequencies desired in accordance with the methods outlined for 25 to 60 cycles, 1000 cycles and 100 to 1500 kilocycles as described in the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 35 T) of the American Society for Testing Materials.[1] Measurements shall be made at the frequencies to which the material will be subjected in service unless otherwise specified. When using a cell in making power factor and dielectric constant determinations, measurements shall be made at the temperature desired, first with air as dielectric and then with the compound in the cell as dielectric.

Calculations

47. The power factor shall be calculated in accordance with the Tentative Methods D 150 - 35 T,[1] and the dielectric constant shall be determined for any given compound from the ratio of the capacitance of the cell with the compound as dielectric to the capacitance of the cell with air as dielectric. When the specimen under determination is in the form of a disk the air capacitance shall be calculated from the dimensions of the electrodes and the thickness of the dielectric. In this case, correction shall be made as outlined in the Tentative Methods D 150 - 35 T.[1] When the sample has been poured between electrodes being held apart by separators, the air capacitance can be measured directly the same as with the cell, or it may be calculated from the dimensions of the electrodes and the thickness of the separators, taking into account the edge correction.

Report

48. The report shall include the following:

(*a*) The type of cell used and the dimensions of the same.

(*b*) The method used and the frequency at which measurements were made.

(*c*) The voltage across the specimen during the test.

(*d*) The dielectric constant, the power factor, and the respective temperatures at which the determinations were made.

(*e*) A statement of the approximate accuracy of the determinations.

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[1] See p. 1044.

APPENDIX I

DEGASIFICATION OF SOLID FILLING AND TREATING COMPOUNDS

Compounds having high viscosity may be degasified by heating in a vacuum oven or in a cell fitted with a special cover with vacuum connection similar to the cover shown in Fig. A1, Appendix II.

In either method the temperature and vacuum should be high enough and the time long enough to insure the driving off of mechanically entrapped gases, but should tend to decompose the compound as little as possible. A gas-free condition is indicated when bubbles of gas no longer appear at the surface of the compound.

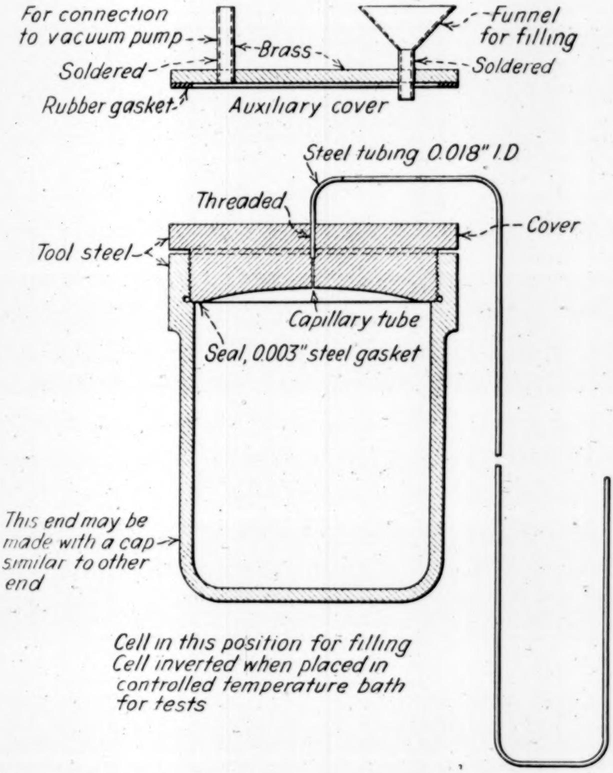
For connection to vacuum pump
Brass
Funnel for filling
Soldered
Soldered
Rubber gasket
Auxiliary cover
Steel tubing 0.018" I.D
Threaded
Cover
Tool steel
Capillary tube
Seal, 0.003" steel gasket
This end may be made with a cap similar to other end
Cell in this position for filling
Cell inverted when placed in controlled temperature bath for tests

FIG. A1.—Metallic Cell for Coefficient of Expansion Determinations.

APPENDIX II

CELL FOR DETERMINING COEFFICIENT OF EXPANSION OF SOLID FILLING AND TREATING COMPOUNDS

Figure A1 shows the metallic cell for coefficient of expansion determinations. The cell consists of four principal parts: A steel cylinder, a metallic gasket, a steel cover, and a dummy or auxiliary cover for filling. The gasket must be of a metal which does not amalgamate with mercury.

The cylinder is about 2.5 in. (6.35 cm.) in internal diameter, and approximately 3 in. (7.6 cm.) in internal depth. The top of the cylinder is threaded to receive the steel cover and has a machined shoulder to seat a 0.003 in. thick metallic gasket. The cylinder may be of one piece construction or fitted with a cap at the bottom similar to the top end.

The steel cover is carefully rounded on the under side to avoid air pockets. It is threaded into the top of the cylinder and seats on the metallic gasket. The center of the cover is threaded to receive a steel capillary tube of 0.018 in. in internal diameter.

The auxiliary cover is brass with a rubber gasket seated by atmospheric pressure. A brass funnel and vacuum connection are soldered to the cover. A plug is provided for sealing the funnel while the cell is maintained under the vacuum specified after filling.

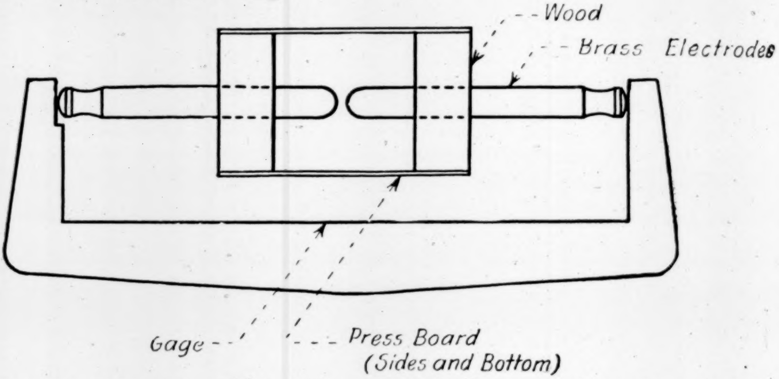

FIG. A2.—Container, Showing Electrodes in Place for Dielectric Strength Test.

APPENDIX III

DEVICE FOR DETERMINING DIELECTRIC STRENGTH OF SOLID FILLING AND TREATING COMPOUNDS

Because of the great difficulty experienced in removing most solid filling and treating compounds from the container and from the electrode an arrangement is desirable which is sufficiently inexpensive to permit of its being discarded fully or in part after the test. Two devices that have proved satisfactory are illustrated in Figs. A2 and A3.

Figure A2 shows the simplest device. It consists of a box about 2 in. square in cross-section and 2 in. in length inside of the wooden ends. The sides and bottom are made from a single piece of press board and are attached to wooden blocks which form the ends. Holes drilled through the wooden blocks receive the electrodes which are turned from ½ in. diameter brass rod. To facilitate adjustment of the gap length, a gage is arranged to slip over the ends of the electrode and so regulate the gap to the desired value.

Figure A3 shows a more elaborate type of testing device consisting of a framework made from laminated phenol fiber about 8 in. (20 cm.) in length and 2¼ in. (5.7 cm.) square with brass bushings centrally inserted in each end member to hold the electrode rods. A box of heavy paper or pasteboard is arranged to fit loosely inside the framework. The electrodes, which are separable by means of screw joints, are inserted through small holes in the ends of the paper box and clamped to make an oil-tight joint. The proper electrode spacing may be obtained by means of an adjusting screw on the right-hand end. Changes in the electrode spacing with temperature can be reduced greatly (to less than 0.001 in. in a change of temperature of 75 C.) by the indicated electrode design.

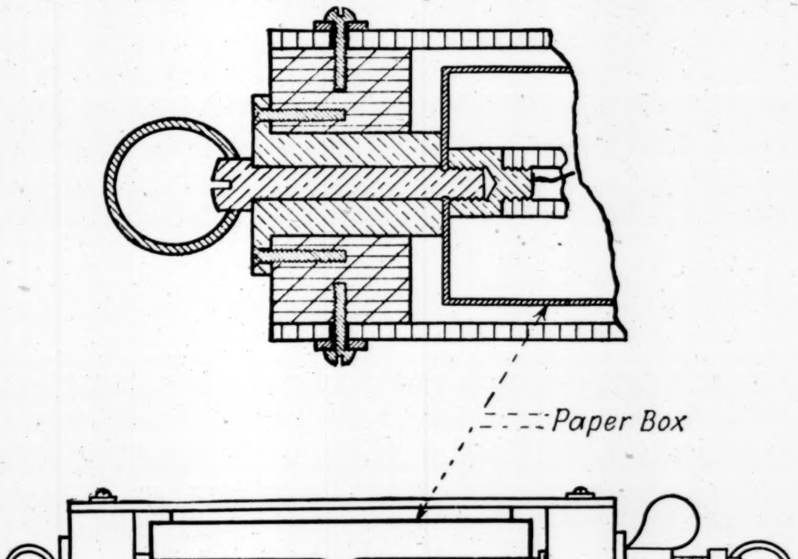

FIG. A3.—Container, Showing Electrodes in Place for Dielectric Strength Test.

Phenol fiber of suitable coefficient of expansion is used for supporting the brass hemispherical electrode tips and electrical connection is made by a copper wire through the center of the fiber rod. The volume of the container may be reduced to accommodate small samples by the insertion of wedges of carefully dried wood into the corners of the paper box.

APPENDIX IV

MEASURING CELL FOR RESISTIVITY, POWER FACTOR AND DIELECTRIC CONSTANT MEASUREMENTS OF SOLID FILLING AND TREATING COMPOUNDS

A conductivity cell that has been developed for the purpose of measuring the volume resistivity as well as other electrical constants of solid filling and treating compounds and oil is shown in Fig. A4. The concentric cylinder type of cell was chosen after experimenting with various types for the following points of simplicity and efficiency:

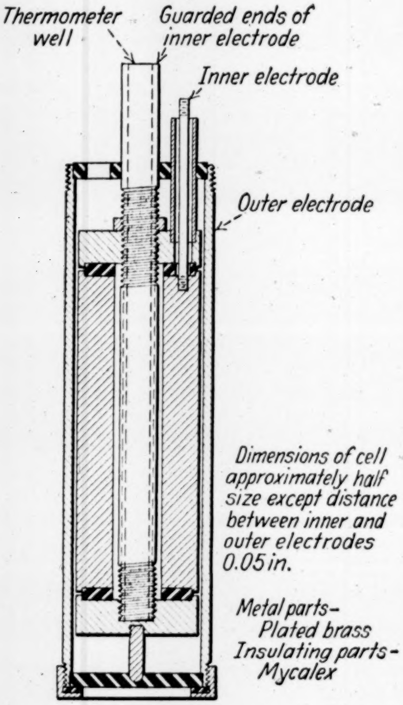
Thermometer well
Guarded ends of inner electrode
Inner electrode
Outer electrode
Dimensions of cell approximately half size except distance between inner and outer electrodes 0.05 in.
Metal parts- Plated brass
Insulating parts- Mycalex

FIG. A4.—Apparatus for Volume Resistance – Temperature Characteristics Test.

1. Ease of insulating electrodes.
2. Large area of electrodes in compact form, the outer one of which also serves as container for the compound. This outer electrode is also exposed directly to the heating medium and aids in rapid changes from one temperature to another and also promotes uniform temperature distribution to the comparatively thin layer of compound in contact with it.
3. Comparative ease in assembling and disassembling cell and cleaning.

This type of cell permits the use of a very small amount of insulating material to insulate the electrodes. Mycalex has been found to be a satisfactory material for this purpose due to the fact that it can be machined to size and has good insulation resistance characteristics over the temperature range at which these compounds are normally tested. Also, it apparently is unaffected by the solvents used in the cleaning operation.

A suggested method of cleaning the cell is to remove the bottom retaining ring and to hang the cell in an oven by a hook fastened through a hole drilled in the protruding stem. Upon heating, the outer cylinder will slide away from the inner electrode and both parts will drain fairly clean of the compound. In order to speed up this cleaning, the flame of a bunsen burner may be applied directly to the cell after removing the cap and suspending the cell by the protruding stem. Further application of the flame to the cylinder and inner electrode after they separate will rapidly remove most of the compound and the final cleaning of each part can be accomplished by suitable solvents.

TENTATIVE METHODS OF TESTING LAMINATED ROUND RODS USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 349 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1934, 1935.

Scope

1. These methods are intended to apply to laminated round rod materials to be used as electrical insulation.

TENSILE STRENGTH

Apparatus

2. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned.

Specimens

3. The specimens shall be about 12 in. in length. When the diameter of the rod is $\frac{1}{4}$ in. or over, a lathe cut 1 in. in width and $\frac{1}{32}$ in. in depth with corners rounded to a radius of 3 in. shall be made around the rod at the center.

Procedure

4. Five specimens shall be tested.

Temperature

5. All tests shall be made at normal room temperature of about 20 C. (68 F.).

Speed of Testing Machine

6. The cross-head speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.05 in. per minute when the machine is running idle.

Report

7. The report shall include the following:

(*a*) The diameter of the specimen expressed to the nearest 0.001 in., determined from at least two measurements 90 deg. apart.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

(*b*) The breaking load of each specimen in pounds or kilograms.

(*c*) The tensile strength of each specimen in pounds per square inch or kilograms per square centimeter.

(*d*) The room temperature.

FLEXURAL STRENGTH

Apparatus

8. (*a*) Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used.

(*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. The distance between the points of support shall be 4 in. when the diameter of rod is $\frac{1}{2}$ in. or over. For smaller rods the distance between supports shall be eight times the diameter of the rod. The load shall be applied through a steel block having a semi-circular contact edge of the same radius as the rod with edges rounded to a radius of $\frac{1}{8}$ in.

Specimens

9. The specimen shall be 5 in. in length.

Procedure

10. Five specimens shall be tested.

Report

11. The report shall include the following:

(*a*) The diameter of the specimen expressed to the nearest 0.001 in., determined from at least two measurements 90 deg. apart.

(*b*) The breaking load of each specimen in pounds or kilograms.

(*c*) The maximum fiber stress in pounds per square inch or kilograms per square centimeter, calculated according to the following formula:

$$S = \frac{8\,WL}{\pi d^3}$$

where S = the maximum fiber stress;
W = the breaking load in pounds or kilograms;
L = the distance between supports in inches or centimeters;
d = the diameter in inches or centimeters.

COMPRESSIVE STRENGTH

Apparatus

12. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable, at the top.

The metal-bearing plates shall be directly in contact with the ends of the test specimen.

Specimens

13. Samples shall be tested as received in specimen lengths of 1 in. The ends shall be accurately cut or ground square with the sides.

Procedure

14. Five specimens shall be tested with the load applied perpendicular to the faces or ends of the specimen.

Report

15. The report shall include the following:

(*a*) The diameter of the specimen expressed to the nearest 0.001 in., determined from at least two measurements 90 deg. apart.

(*b*) The load on each specimen in pounds or kilograms at the first sign of rupture.

(*c*) The ultimate compressive strength in pounds per square inch or kilograms per square centimeter calculated from the data obtained on the application of the load perpendicular to the face of the specimen.

DENSITY

Specimens

16. Two specimens shall be tested. Any suitable size specimen may be used. The samples used for the compressive strength test, Section 13, will be found convenient.

Procedure

17. Any suitable weight-difference apparatus for making readings in water and air, or the weight and dimensions of the specimen may be used as a basis for calculating the density.

Report

18. The report shall express the density in c.g.s. units.

WATER ABSORPTION TEST

Rate of Absorption

Specimen

19. The test specimen shall be 1 in. in length for rods 1 in. in diameter or under, and $\frac{1}{2}$ in. in length for larger diameter rods. The diameter of the specimen shall be the diameter of the rod. The specimen shall be cut from the sample with a smooth cutting saw. The cut edges shall be finished with No. 0 or finer sandpaper or emery

cloth. Sawing and sand-papering operations shall be slow enough so that the material is not heated appreciably. The thickness in inches to the nearest 0.001 in. shall be measured at the center of the specimen.

Procedure

20. To determine the rate of absorption, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hr. at a temperature between 105 and 110 C. (220 and 230 F.), cooled in a desiccator and immediately re-weighed. The difference between the original weight and the dry weight shall be recorded as loss in weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water maintained at a temperature of 25 C. ± 2 C. (77 F. ± 3.6 F.) throughout the test. At the end of 2 hr., the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately, and then replaced in the water. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hr. The percentage of water absorbed in 2 hr. shall be calculated on the weight of the dry specimen.

(*c*) After 24-hr. immersion, the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24-hr. immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hr. The percentage of water absorbed in 24 hr. shall be calculated on the weight of the dry specimen. If the individual 24-hr. absorptions differ by more than 10 per cent from the average absorption of the two specimens, the test shall be repeated.

Report

21. The report shall include the values for each of the two specimens and the average values as follows:

(*a*) The diameter and length of the specimen before the test, to the nearest 0.001 in.

(*b*) The percentage loss in weight on drying calculated on the original weight.

(*c*) The percentage of water absorbed in 2 hr. and in 24 hr. calculated on the dry weight.

TENTATIVE METHODS OF TESTING LAMINATED TUBES USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 348 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1932; Revised, 1932, 1934, 1935.

Scope. 1. These methods are intended to apply to laminated tubes to be used as electrical insulation.

Tensile Strength

Apparatus. 2. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned. Steel or brass plugs, $3\frac{1}{2}$ in. in length and of a suitable diameter with edges rounded to $\frac{1}{16}$-in. radius will be required. The plugs shall fit the specimen to within 0.010 in. They can be conveniently located in the tube by separating and supporting them on a metal rod, the lower end of which is screwed into the lower plug, and the upper end rests in a loose socket as shown in Fig. 1.

Specimens. 3. Test specimens shall be 12 in. in length. Where the wall thickness of tubing is $\frac{1}{8}$ in. or over, a lathe cut 1 in. in width and $\frac{1}{32}$ in. in depth, with corner rounded to a radius of 3 in. shall be made around the tube at the center.

Procedure. 4. Five specimens shall be tested. The average inside and outside diameters determined from at least two measurements 90 deg. apart shall be measured at the groove to the nearest 0.001 in. and the cross-section area shall be calculated from these dimensions. The metal plugs shall be assembled with the tube as shown in Fig. 1. This assembly shall then be grasped in the V-notched jaws of the testing machine.

Speed of Testing Machine. 5. The cross-head speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.05 in. per minute when the machine is running idle.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

Report. 6. The report shall include the following:

(*a*) The average inside diameter of the specimen expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.

(*b*) The average outside diameter of the specimen expressed to the nearest 0.001 in. determined from at least two measurements 90 deg. apart.

(*c*) The average outside diameter of the reduced section expressed to the nearest 0.001 in., if a groove was used.

(*d*) The full wall thickness of the specimen.

(*e*) The net area of the test section.

(*f*) The breaking load of each specimen in pounds or kilograms.

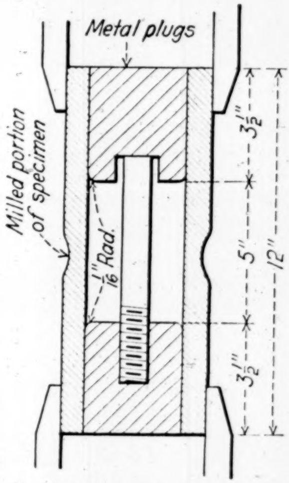

FIG. 1.—Metal Plugs Used for Tension Test, Showing Location of Plugs in Test Specimen.

(*g*) The tensile strength of each specimen in pounds per square inch or kilograms per square centimeter.

(*h*) The room temperature.

COMPRESSIVE STRENGTH

Apparatus. 7. Any standard type of testing machine may be used provided it is accurate to within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable at the top. The metal bearing plates shall be directly in contact with the ends of the test specimen.

Specimens. 8. Samples shall be tested as-received in specimen lengths of 1 in. Care shall be taken in cutting the specimens for the axial test to have the ends of the specimens cut accurately at right angles to the axis of the tube. Specimens which are not cut squarely are likely to give low results on test.

Procedure. 9. Five specimens shall be tested axially, with the load applied perpendicular to the faces or ends of the specimen, and five specimens shall be tested diametrically, with the load applied perpendicular to the tangent at point of application.

Report. 10. The report shall include the following:

(*a*) The average inside and outside diameters of the specimen expressed to the nearest 0.001 in., each determined from at least two measurements 90 deg. apart.

(*b*) The average wall thickness of the specimen expressed to the nearest 0.001 in.

(*c*) The direction of application of the load.

(*d*) The load on each specimen at the first sign of rupture, in pounds or kilograms.

(*e*) The ultimate compressive strength in pounds per square inch or kilograms per square centimeter, calculated from the data obtained on the application of the load perpendicular to the face of the specimen.

WATER ABSORPTION

Specimens. 11. (*a*) Specimens of tubes having inside diameters less than 3 in. shall be the full section of the tube and 1 in. in length. For larger tubes, a rectangular specimen shall be cut 3 in. in length in the circumferential direction of the tube and 1 in. in width lengthwise of the tube.

(*b*) The specimens shall be sawed from the sample so as to have smooth edges free from cracks. The cut edges shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations shall be slow enough so that the material is not heated appreciably. The specimens shall be rinsed with gasoline to remove any oil from the machining operation, wiped with a dry cloth and allowed to stand in air for 2 hours to remove the gasoline.

Procedure. 12. (*a*) The specimen shall be dried in an oven for 1 hour at 105 to 110 C. and cooled in a desiccator. For materials which will not withstand this temperature the drying shall be omitted.

(*b*) The dried specimen shall be immersed in distilled water maintained at a temperature of 25 C. ± 2 C. (77 F. ± 3.6 F.) throughout the test. At the end of 2 hours, the specimen shall be removed from the water, the surface water wiped off with a dry cloth, weighed immediately, and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours' immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours' immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens, the test shall be repeated.

Report. 13. The report shall include the following:

(*a*) The average inside and outside diameters of the specimen.

(*b*) The average wall thickness of the specimen.

(*c*) The percentage of water absorbed in 2 hours and in 24 hours.

DIELECTRIC STRENGTH

Apparatus. 14. A high-voltage transformer as described in Section 2 of the Tentative Methods of Testing Sheet, Tape and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 - 34 T) of the American Society for Testing Materials,[1] shall be used. The inner electrode shall consist of a brass rod 3 in. in length with edges rounded to $\frac{1}{4}$-in. radius. This should fit snugly inside of the tube to be tested. It shall be fitted with a binding post on one end. The outer electrode shall consist of a strip of metal foil $2\frac{1}{2}$ in. in width and long enough to extend around the circumference of the tube.

Specimens. 15. Specimens for the dielectric strength test shall be 12 in. in length.

Procedure. 16. Five specimens shall be tested. The brass rod inner electrode shall be placed directly in the center of the tube and for the outside electrode a strip of metal foil $2\frac{1}{2}$ in. in width shall be wrapped around the tube. The tubes shall be immersed in oil and all tests shall be made at room temperature. Short-time and step-by-step tests shall be made in accordance with the Tentative Methods of Testing Sheet, Tape and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 - 34 T) of the American Society for Testing Materials.[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 982 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 980.

REPORT

Report. 17. The report shall include the following:

(*a*) The inside and outside diameters of the specimen expressed to the nearest 0.001 in.

(*b*) The wall thickness of the specimen expressed to the nearest 0.001 in.

(*c*) The breakdown voltage of each specimen.

(*d*) The average breakdown voltage of all specimens.

(*e*) The average dielectric strength in volts per mil.

DENSITY

Specimens. 18. Two specimens shall be tested. Any suitable size specimen may be used. The specimen 1 in. in length used for the water absorption test, Section 11, will be found convenient.

Procedure. 19. Any suitable weight-difference apparatus for making readings in water and air, or the weight and dimensions of the specimen may be used as a basis for calculating the density.

Report. 20. The report shall express the density in c. g. s. units.

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Phase Difference and Dielectric Constant. 21. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 35 T) of the American Society for Testing Materials.[1]

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[1] See p. 1044.

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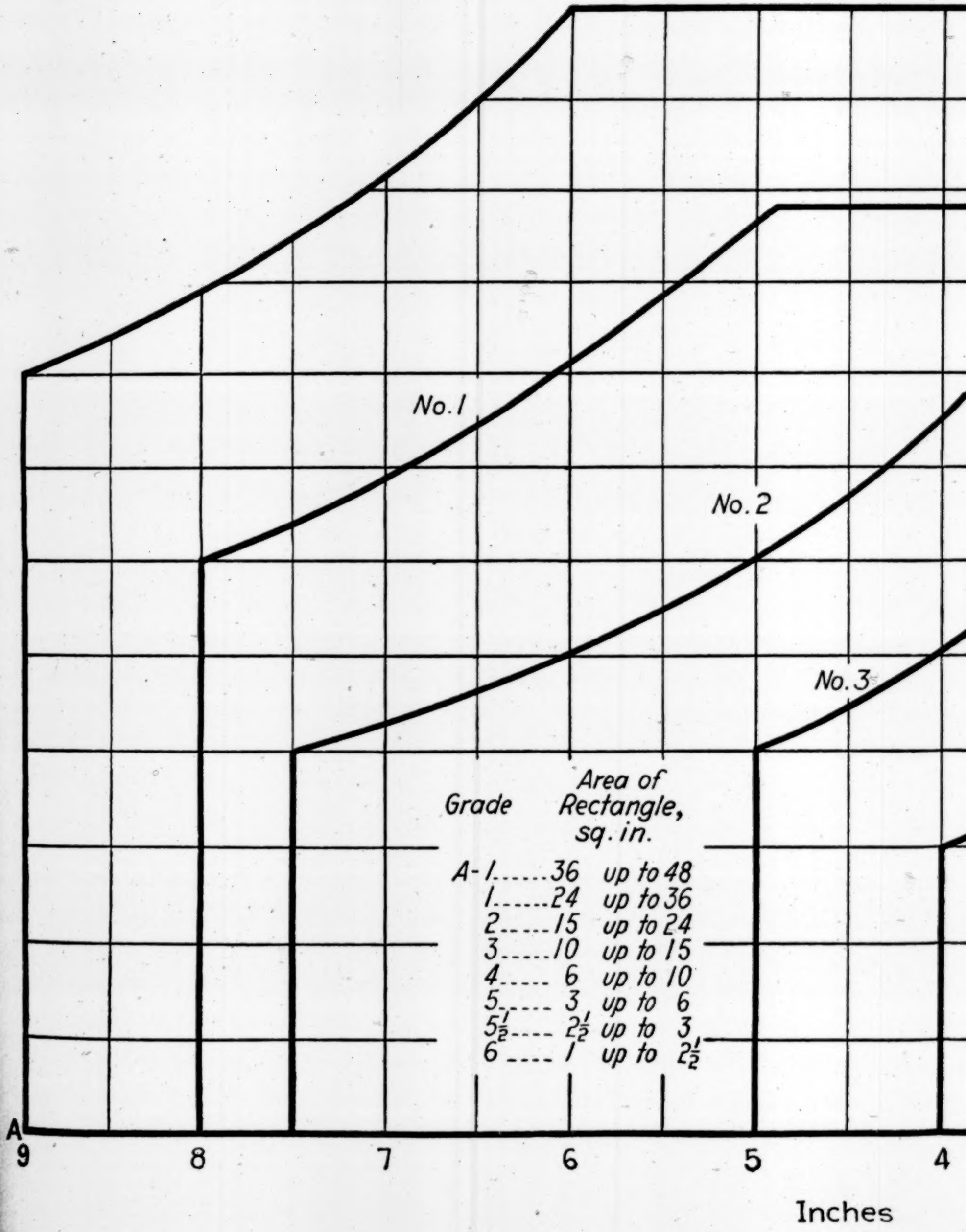
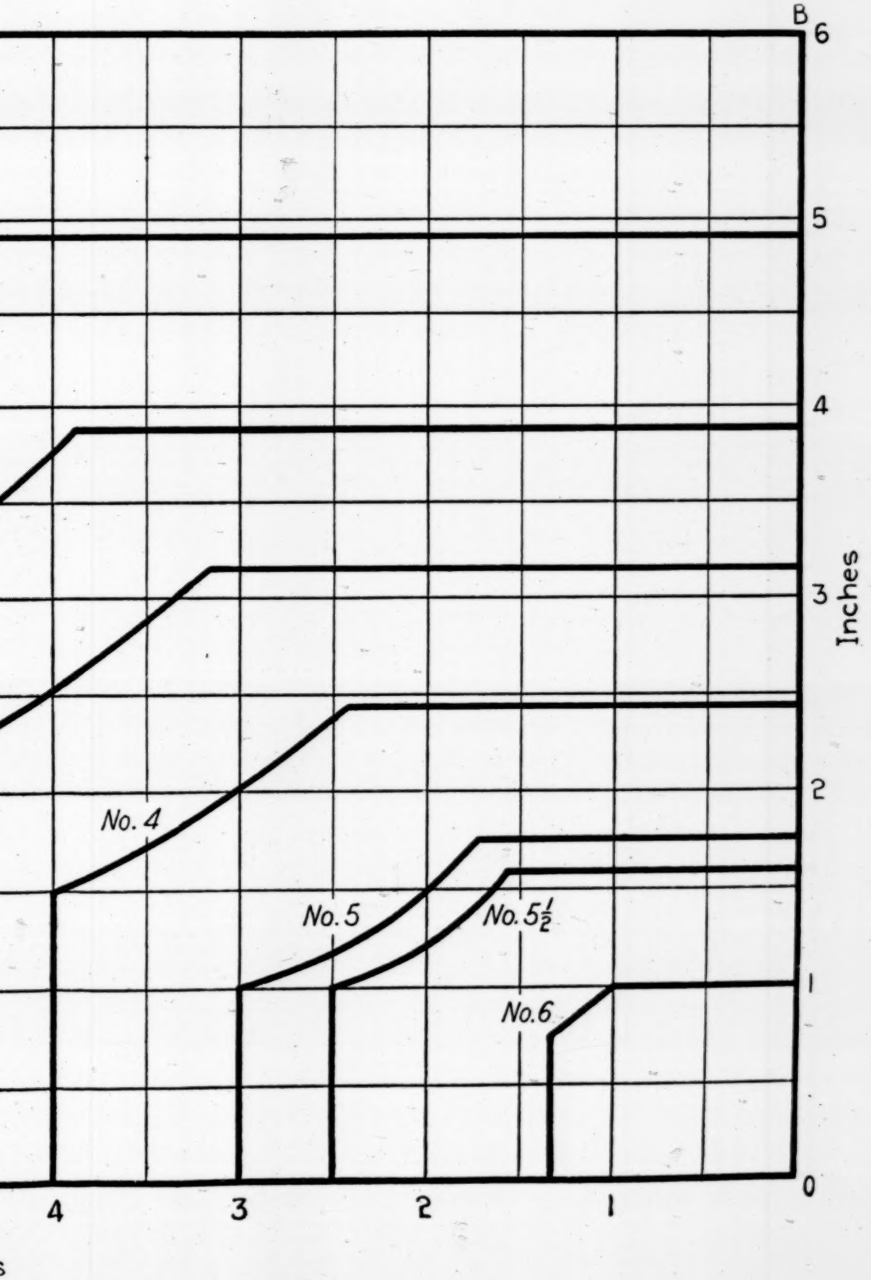


Grade	Area of Rectangle, sq. in.
A-1	36 up to 48
1	24 up to 36
2	15 up to 24
3	10 up to 15
4	6 up to 10
5	3 up to 6
5½	2½ up to 3
6	1 up to 2½

FIG. 1.—A.S.T.M. Chart for Grading Natural Block Mica

PLATE IV.
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 35, PART I

TENTATIVE METHODS OF TEST FOR
GRADING NATURAL MICA
A.S.T.M. DESIGNATION: D 351 - 35 T



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TENTATIVE METHODS OF TEST
FOR
GRADING NATURAL MICA[1]

A.S.T.M. Designation: D 351 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1932; Revised, 1933, 1935.

Scope. 1. These methods cover tests for the grading of all natural block mica and mica splittings for general use according to size, commercial quality, and thickness.

Grading According to Size

Grade. 2. Natural mica shall be graded according to the area of the usable rectangle which can be cut from the specimen and the minimum dimension of one side. The mica in the usable rectangle shall meet the quality requirements specified by the purchaser.

A.S.T.M. Chart. 3. The tentative standard A.S.T.M. chart shown in Fig. 1 (Plate IV) shall be used for grading natural block mica and mica splittings according to size.

Method of Grading for Size. 4. The specimen to be graded shall be laid upon the chart so that it covers point *O* and has its maximum and minimum dimensions extending along and covering the lines *OA* and *OB*, respectively. The specimen should be shifted until its usable area completely covers the largest rectangle determined by a diagonal extending from point *O* to or beyond a point on any of the curves, Nos. 6, 5½, 5, 4, 3, 2, 1, or A-1. The number of the curve at greatest distance from *O* cut by the diagonal of the rectangle designates the grade of the specimen.

Note.—The A.S.T.M. chart complies closely with the following so-called India grading scale, in general use for many years:

Grade	Area of Rectangle, sq. in.	Minimum Dimension of One Side
Extra Special	60 to 80	....
Special	48 to 60	....
A-1	36 to 48	4 in.
1	24 to 36	3 in.
2	15 to 24	2 in.
3	10 to 15	2 in.
4	6 to 10	1½ in.
5	3 to 6	1 in.
5½	2½ to 3	1 in.
6	1 to 2½	¾ in.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

DETERMINATION OF COMMERCIAL QUALITY

Commercial Quality.

5. The commercial quality of mica shall be judged in terms of the following scale:

QUALITY	DESCRIPTION
Clear	Free of all mineral and vegetable inclusions, stains, air inclusions, waves or buckles. Hard transparent sheets.
Clear and Slightly Stained	Free of all mineral and vegetable inclusions, cracks, waves, and buckles but may contain slight stains and air inclusions.
Fair Stained	Free of mineral and vegetable inclusions and cracks. Hard. Contains slight air inclusions and is slightly wavy.
Good Stained	Free of mineral inclusions and cracks but contains air inclusions, some vegetable inclusions and may be somewhat wavy.
Stained	Free of mineral inclusions and cracks but may contain considerable clay and vegetable stains and may be more wavy and softer than the better qualities.
Black Stained or Spotted	Same as Stained but contains mineral inclusions.

NOTE.—It is proposed to prepare a set of master standards complying with the above descriptions, from which sets of photographic prints or transparent autochrome plates can be furnished.

THICKNESS

Thickness.

6. (*a*) Measurements of the thickness of mica shall be determined with a machinist's micrometer as specified in the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 34 T) of the American Society for Testing Materials.[1] In determining thickness of mica which must be held to close tolerance or where two or more specimens are to be measured at once, Method A shall be used. Where the maximum accuracy is not required, Method B may be used.

(*b*) Because of the abrasive nature of mica, the micrometer shall be tested frequently for conformity to the requirements specified in the Tentative Methods D 374. The anvil and spindle shall be cleaned as frequently as necessary to prevent the accumulation of mica dust on their surfaces and to preserve the accuracy of the measurements. To clean, the micrometer shall be closed lightly on a clean sheet of bond paper and the paper moved between the surfaces.

NOTE.—Care must be exercised in moving from one measurement location to another to maintain the surfaces of the anvil and spindle parallel to the surfaces of the specimen at all times so as to avoid scratching the mica and accumulating mica dust under the micrometer surfaces which will cause false readings.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1069 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1087.

TENTATIVE METHODS OF TESTING MOLDING POWDERS USED IN MANUFACTURING MOLDED ELECTRICAL INSULATORS[1]

A.S.T.M. Designation: D 392 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.

Scope

1. These methods cover tests for certain physical properties of molding powders, used for the manufacture of electrical insulators and other plastic molded parts. These powders consist of an organic binder of either the thermo-plastic or heat-reactive type and organic or inorganic fillers or mixtures of such fillers.

SAMPLING

Purpose

2. This sampling procedure is intended for obtaining a representative sample of a batch or shipment of molding compound from the manufacturer's original packages.

Procedure

3. (*a*) If the complete shipment is indicated by the manufacturer's marking to consist of only one batch or "run" of material, the number of packages selected for sampling shall be not less than 10 per cent of the packages in the batch, and in any case, not less than 3 packages. The packages selected for sampling may be chosen at random, or in case the manufacturer has marked the packages to indicate the order in which they were filled from his batch, the selection may be made with reference to this order of filling, if desired by the purchaser. If the shipment consists of more than one batch or "run" of material, each batch shall be sampled separately to produce one composite blended sample for examination for each batch in the shipment.

(*b*) The packages selected shall be opened carefully, making sure that no contamination enters them from scale, paint, shattered heads, torn liners, or other causes. From each standard size drum sampled, an equal number of scoopfuls of material shall be taken from a point about 3 in. below the surface. From smaller packages the sample shall be taken from a point 1 in. below the surface. The material shall be transferred to a clean, dry, sheet metal or glass container, capable of being tightly closed. The gross quantity of sample taken shall be approximately twice that estimated to be required for the tests which are to be made. This allowance is made in order to permit repeat tests without re-sampling. The composite sample shall be blended thoroughly before using for the desired tests.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

NOTE.—Drums of molding powder in transit, and frequently during packing at the manufacturers' plant, become shaken down and frequently are so densely compacted that only a few ounces of material would fall out if the container were inverted. The few coarse particles not bound in the mass show plainly on the top surface, giving the impression that the fines have sunk and the coarse particles risen. A check-up by sieve analysis of samples taken just under the surface, and throughout the drum, ordinarily fails to disclose segregation.

PARTICLE SIZE DETERMINATION OR SIEVE ANALYSIS

Scope

4. Two procedures, Methods *A* and *B*, are given for determining the size distribution of the particles in the molding powder being examined. Method *A* is a complete sieve analysis and Method *B* a shorter check method by which the relative quantities of coarse and fine particles in a powder may be readily determined.

Method A

General Description

5. The test is made by distributing the powder on a series of sieves of different mesh openings and determining the weight of material retained by each sieve after thorough shaking.

Apparatus

6. (*a*) *Sieves.*—The sieves used shall be of the U. S. Standard Sieve Series, half-height, 8 in. in diameter, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1] The following sieves together with a cover and bottom pan will be required:

U. S. STANDARD SIEVE SERIES NUMBER	SIEVE OPENING, MICRONS
No. 12	1680
No. 20	840
No. 40	420
No. 70	210
No. 140	105

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

(*b*) *Machine Sieving Device.*—There will also be required a mechanical sieve-shaking device and an automatic time switch or equivalent device.

(*c*) *Balance.*—A sensitive laboratory balance of 500-g. capacity, sensitive to 0.1 g., shall be used for weighing the sample and the residue retained on the sieves. Other accessories required are suitable brushes for cleaning the sieves, paper for collecting samples and any other items of equipment ordinarily used in making a sieve analysis.

Method

7. The sieves specified in Section 6 shall be stacked together in the order of size opening with the coarsest on top and the pan on the bottom. A 100-g. sample (Note 1) shall be accurately weighed and transferred to the top sieve of the stack which shall then be covered. The stack of sieves shall then be placed in the machine sieving device and shaken for 10 min., ± 15 sec. After shaking, the stack of sieves shall then be carefully separated, beginning at the top, and the amount of material retained on each sieve and in the bottom pan shall be determined by weighing. In transferring the powder from the sieve to the weighing scale, care shall be taken to brush clean from the back of the sieve all adhering particles. The cumulative percentage of original sample retained on each sieve and in the bottom pan shall be calculated (Note 2).

Report

8. The report shall include the following:

(*a*) the actual percentage of material retained on each sieve, and

(*b*) the cumulative total percentage of material retained on each sieve and in the bottom pan.

Method B

General Description

9. The test is made by distributing the powder on one coarse and one fine sieve and determining the weight of the material retained on each sieve after thorough shaking.

Apparatus

10. (*a*) *Sieves.*—The sieves used shall be of the U. S. Standard Sieve Series conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[1] The sieves required are the No. 12 (1680-micron) and No. 140 (105-micron) together with a cover and bottom pan.

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[1] **1933 Book of A.S.T.M. Standards, Part II, p.** 1244.

(*b*) *Mechanical Sieving Device.*—There will also be required a mechanical sieve-shaking device and an automatic time switch or equivalent device.

(*c*) *Balance.*—A sensitive laboratory balance of 500-g. capacity, sensitive to 0.1 g., shall be used for weighing the sample and the residue retained on the sieves. Other accessories required are suitable brushes for cleaning the sieves, paper for collecting samples and any other items of equipment ordinarily used in making a sieve analysis.

Method

11. The No. 12 sieve shall be stacked on the No. 140 sieve with the pan underneath. A 100-g. sample (Note 1) shall be accurately weighed and transferred to the No. 12 sieve, which shall then be covered. The stack of sieves shall then be placed in the machine sieving device and shaken for 10 min., ±15 sec. After shaking, the sieves shall be carefully separated and the amount of material retained on each sieve and in the bottom pan shall be determined by weighing. In transferring the powder from the sieve to the weighing scale, care shall be taken to brush clean from the back of the sieve all adhering particles. Weigh and record the weights from each sieve and the pan separately and calculate the percentages retained on the No. 12 and through the No. 140 sieve (Notes 2 and 3).

Report

12. The report shall include the two percentages of coarse and fine material, respectively, as calculated in Section 11. Note should be made of any unusually large particles found on the No. 12 sieve.

NOTE 1.—If necessary this test may be made on a sample of any size from 50 to 200 g. The weight of sample used shall be stated in the report.

NOTE 2.—Ordinarily there is a small loss of dust indicated by the cumulative total of actual weight being less than 100 per cent. If this loss is not over 2 per cent, the amount reported through the finest sieve shall be increased until the total of all portions of the sample equal 100 per cent. If the cumulative total of actual weight is less than 98 per cent, the weights and operations shall be carefully checked and the work repeated, if necessary.

NOTE 3.—The consumer will probably be interested in particle size only along lines rather definitely restricted as follows:

First, particles substantially larger than normal sieve size, such as might be present due to broken screen wire in the manufacturers' plant, would tend to stop up tablet machine hoppers, give irregular tablet weights, and rough or streaked molded surfaces. Ordinarily a single coarse sieve provides a satisfactory check, that is, the No. 12 given in Method B.

Second, an excess of very fine particles would tend to cause excessive dusting, high bulk factor and irregular tablet weights due to failure to pour freely. (The amount may be determined by the use of the No. 140 sieve in Method B.) A certain amount of the finest particle sizes is usually desirable for improving finish and reducing bulk factor. Excessive fines may be indicated better by bulk factor and pourability than by sieve test.

APPARENT DENSITY

Purpose

13. The apparent density test is intended to determine the fluffiness or bulk of molding powder in loose condition by weighing and measuring a standard quantity of the loose powder.

Apparatus

14. The apparatus shall consist of the following:

(*a*) *Measuring Cup.*—A cylindrical measuring cup of 100-cc. capacity having a diameter equal to half the height. Such a cylinder would be 1.572 in. (3.99 cm.) in inside diameter by 3.144 in. (7.98 cm.) in inside height.

(*b*) *Funnel.*—A funnel mounted as shown in Fig. 1.

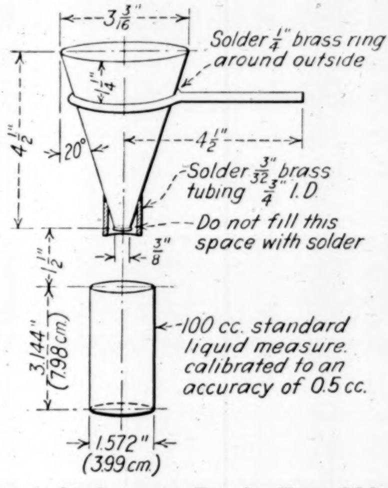
3 3/16"
Solder 1/4" brass ring around outside
1 1/4"
4 1/2"
20°
4 1/2"
Solder 3/32" brass tubing 3/4" I.D.
Do not fill this space with solder
3/8"
1 1/2"
3.144" (7.98 cm.)
100 cc. standard liquid measure. calibrated to an accuracy of 0.5 cc.
1.572" (3.99 cm.)

FIG. 1.—Apparatus for Apparent Density Test of Molding Powders.

Procedure

15. A well-mixed 120-cc. sample shall be selected from the general samples of powder. With the apparatus assembled as shown in Fig. 1, the small end of the funnel shall be closed with the hand or with a suitable flat strip of material and the 120-cc. sample poured into the funnel. The bottom of the funnel shall then be opened quickly and the material allowed to flow freely into the cup. If caking occurs in the funnel the powder may be loosened with a small glass rod. After all the material has passed through the funnel, the excess powder on the top of the cup shall be scraped off with a straight edge. The material in the cup shall then be accurately weighed to the nearest 0.1 g. The weight, in grams, of 1 cc. of powder shall then be

calculated (Note 1). Three determinations of the apparent density shall be made on each sample and the results averaged (Note 2).

Report

16. The report shall include each value of apparent density and the average apparent density.

NOTE 1.—To convert grams per cubic centimeter to ounces per cubic inch multiply by 0.576. To convert grams per cubic centimeter to grams per cubic inch multiply by 16.38.

NOTE 2.—Apparent density figures are not comparable except on compounds having the same specific gravity after molding.

BULK FACTOR

Bulk Factor

17. Bulk factor is the ratio of the volume of any given quantity of loose molding powder to the volume of the same material after molding. By suitable transformation of this ratio, it will be found that the bulk factor is also equal to the ratio of the specific gravity after molding to the apparent density of the loose molding powder.

Procedure

18. (*a*) *Apparent Density.*—The apparent density of the molding powder shall be determined as described in Sections 13 to 16.

(*b*) *Specific Gravity.*—The specific gravity of the molding powder (after molding) shall be determined by any accurate method; such as, weighing two or more samples molded from the molding powder in air and in water. The average result obtained shall be used. If the shape of the piece is such that the volume may be readily calculated from the dimensions, it will be satisfactory to use this calculated volume in place of that determined by loss of weight in water.

(*c*) *Calculation.*—The bulk factor shall be calculated by dividing the average specific gravity of the molded piece by the average apparent density (in grams per cubic centimeter) of the molding powder.

Report

19. The report shall include the average apparent density and specific gravity and the bulk factor (Note) calculated from them.

NOTE.—The bulk factor test is comparable as between all grades of molding compound, regardless of the specific gravity after molding.

POWDER POURABILITY

Purpose

20. The powder pourability test is to determine how readily molding powders will feed through the hoppers and deliver uniform weights of material into the dies of tableting machines by measuring

the time of flow of a standard quantity through a standard funnel. The test is generally adaptable quantitatively only to materials of bulk factor 3.0 or less (see Section 17).

Apparatus

21. The apparatus required consists of a funnel mounted as shown in Fig. 1, and a stop watch.

Procedure

22. A sample of the powder, equivalent to 100 times the molded specific gravity in grams (see Section 18 (*b*)) shall be taken. This sample shall be worked on a paper until there is no tendency of the material to pack or cake. With the apparatus assembled, as shown in Fig. 1, the small end of the funnel shall be closed with the hand or with a suitable flat strip of material, and the sample poured lightly into the funnel, avoiding any tendency to pack it. The bottom of the funnel shall then be opened quickly, and the stop watch shall be started at the same instant. The powder shall be allowed to run from the funnel as freely as it will and the watch shall be stopped at the instant the last grains leave the funnel.

Note.—Correct mold charges are those weights which produce the constant molded volume of the piece to be molded and shall be so measured. Comparable quantities of material for this test are therefore some multiple of the molded specific gravity, 100 being taken as convenient.

Report

23. The report shall state the time in seconds required for the funnel to discharge or that the material will not run through the funnel, if so found (Note).

Note.—Molding powders which are not measurable by this test generally do not feed well without special feeders.

TENTATIVE METHODS OF TESTING ELECTRICAL INSULATING MATERIALS FOR POWER FACTOR AND DIELECTRIC CONSTANT[1]

A.S.T.M. Designation: D 150 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1922; Revised, 1923, 1927, 1931, 1932, 1934, 1935.

Scope.

1. These methods provide for the determination of the power factor and dielectric constant of solid electrical insulating materials at frequencies in the order of:

(*a*) 100 to 1500 kilocycles, the procedure being described in Sections 12 to 23, inclusive;

(*b*) 1000 cycles, the procedure being described in Sections 24 to 30, inclusive.

(*c*) 25 to 60 cycles, the procedure being described in Sections 31 to 36, inclusive.

DEFINITIONS

Power Factor.

2. *Power Factor.*—The power factor of an insulating material is the ratio of the total power loss (watts) in the material to the product of voltage (volts) and current (amperes) in a capacitor in which that material is the dielectric.

Dielectric Constant.

3. *Dielectric Constant.*—The dielectric constant of an insulating material is the ratio of the equivalent parallel capacitance (see Fig. 3) of a capacitor in which that material is the dielectric to the capacitance of a similar capacitor in which the dielectric is a vacuum. (For practical purposes air dielectric is equivalent to a vacuum.)

Loss Factor.

4. *Loss Factor.*—For the purpose of these methods the loss factor of an insulating material is the product of its dielectric constant and the cotangent of its phase angle (θ, Figs. 2 and 4).

Note.—When the cosine of the phase angle is less than 0.1, the cosine and cotangent are practically equal, and loss factor may be calculated from the following formula:

$$\text{Loss factor} = \text{Dielectric Constant, } K \times \text{Power Factor}$$

THEORY OF TEST

Power Factor.

5. (*a*) *Series Notation.*—Any insulating material between two electrodes constitutes a capacitor. Such a physical capacitor may be

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

represented by a capacitance C and a resistance R in *series* as shown in Fig. 1. The resistance R is called the equivalent series resistance and the capacitance C is called the equivalent series capacitance of the capacitor. For sine-wave voltage and current the vector relations are as shown in Fig. 2. The power factor is:

$$\text{Power Factor} = \cos\theta = \sin\Psi = \sin\tan^{-1} R\omega C$$

where R = the resistance in ohms;
ω = 2π times the frequency in cycles; and
C = the capacitance in farads.

Since, for small angles the sine is substantially equal to the tangent, the power factor equals $R\omega C$, approximately. This is correct to closer than 0.5 per cent of the power factor value for power factors up to 0.1. Where R is expressed in ohms, C in microfarads and the frequency, f, in kilocycles, this expression becomes:

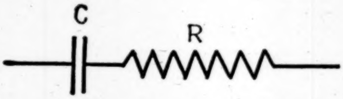

FIG. 1.—Equivalent Series Circuit.

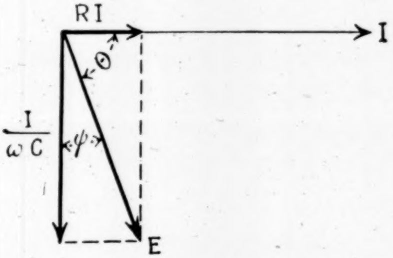

FIG. 2.—Vector Diagram for Equivalent Series Circuit.

$$\text{Power Factor} = 6.28\, RCf \times 10^{-9}$$

The power factor is, therefore, determined by measuring the values of R and C. This may be done by the Substitution Method as described in Sections 15 and 16.

(*b*) *Parallel Notation.*—A physical capacitor may also be represented by a capacitance C_p and a resistance R_p in *parallel* as shown in Fig. 3. The resistance R_p is called the equivalent parallel resistance and the capacitance C_p is called the equivalent parallel capacitance of the capacitor. For sine-wave voltage and current the vector relations are as shown in Fig. 4. For this notation the power factor is:

$$\text{Power Factor} = \cos\theta = \sin\Psi = \sin\tan^{-1}\frac{G}{\omega C_p}$$

where G = the conductance in *mhos;*
ω = 2π times the frequency, in cycles; and
C_p = the capacitance in farads.

Making the same approximations as in Paragraph (*a*), the power factor for practical purposes is taken as $\frac{G}{\omega C_p}$. Where G is expressed in micro-mhos, the frequency, f, in kilocycles, and C_p in micro-microfarads, this expression becomes:

$$\text{Power Factor} = 1.59\,\frac{G\,10^2}{fC_p}$$

It will be seen that G and C_p determine the power factor. They may be measured by the Bridge Method as described in Sections 20 and 21.

The equivalent series capacitance C as determined by the Substitution Method, Sections 15 and 16, and the equivalent parallel capacitance C_p as determined by the Bridge Method, Sections 19 and 20, are not identical; but for power factors up to 0.1 they are equal to within 1 per cent. Either value may be used in calculating the dielectric constant.

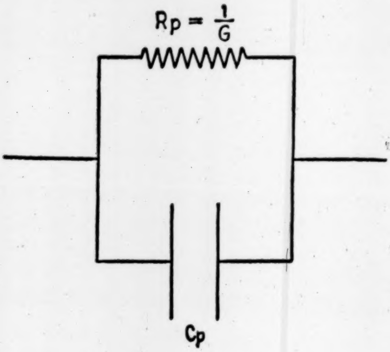

FIG. 3.—Equivalent Parallel Circuit.

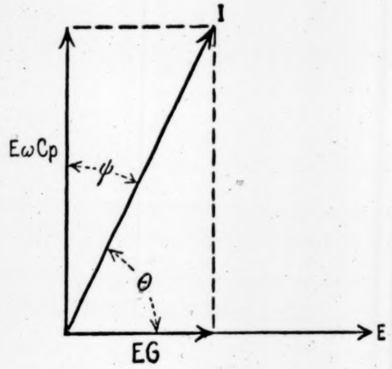

FIG. 4.—Vector Diagram for Equivalent Parallel Circuit.

Dielectric Constant.

6. (*a*) *Sheet Materials.*—For sheet materials, the dielectric constant, K, may be calculated from the following formula:

$$\text{Dielectric constant, } K = \frac{(C - C_e)t}{0.0885A}$$

where t = the average thickness of dielectric between electrodes, in centimeters;

A = the contact area of either of the equal electrodes in square centimeters;

C = the measured capacitance in micro-microfarads;

C_e = the edge correction obtained from the curve in Fig. 5.[1]

The determination of C_e requires a knowledge of the approximate value of K which can always be obtained by making a preliminary calculation, neglecting C_e in the above formula. For thickness t, in inches, and area A, in square inches, the above formula becomes:

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[1] For details of the determination of the edge correction, see E. L Hoch, *Bell System Journal*, Vol. V, pp. 555-572c, October, 1926.

$$\text{Dielectric constant, } K = \frac{(C - C_e)\,t}{0.224\,A}$$

(*b*) *Tubes.*—For materials in the form of tubes, the dielectric constant, K, may be calculated from the following formula:

$$\text{Dielectric constant, } K = \frac{3.6\,t\,(C_1 - C_2)}{D\,(l_1 - l_2)}$$

where t = the thickness of the tube in centimeters;
D = the mean diameter in centimeters;

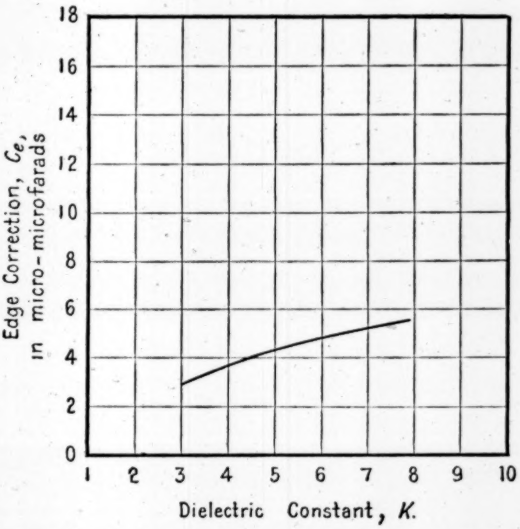

FIG. 5.—Edge Correction Curve for 4.5-in. Diameter Electrodes.

C_1 = the measured capacitance in micro-microfarads when the electrodes have a length of l_1 centimeters; and
C_2 = the measured capacitance in micro-microfarads when the electrodes have a length of l_2 centimeters.

NOTE.—The two measurements C_1 and C_2 are made with different electrode lengths l_1 and l_2 for correction of edge effect.

If the tube thickness is so small, or the electrode length so large that the edge correction may be neglected, then the dielectric constant, K, may be calculated from the following:

$$\text{Dielectric constant, } K = \frac{3.6\,t\,C}{D\,l}$$

where C = the measured capacitance in micro-microfarads for electrodes of length l centimeters.

Loss Factor. 7. The power loss per unit volume of insulating material for a stated frequency, voltage gradient and temperature is proportional to the product of its dielectric constant and the cotangent of its phase angle (θ, Figs. 2 and 4). Therefore, the loss factor is defined as:

Loss Factor = Dielectric Constant, $K \times$ Cotangent of Phase Angle, θ

NOTE 1.—Sine-wave voltage is assumed.

NOTE 2.—When the cosine of the phase angle is less than 0.1, the cosine and cotangent are practically equal, and loss factor may be calculated from the following formula:

Loss Factor = Dielectric Constant, $K \times$ Power Factor

TEST SPECIMENS

Test Specimens. 8. (*a*) *Molded, Sheet, or Ceramic Materials.*—For testing molded, sheet, or ceramic materials (see also Tubes, Paragraph (*c*)) the test specimen shall be either a disk 6 in. (15.24 cm.) in diameter or a square 6 in. (15.24 cm.) on a side. The thickness shall preferably not be less than 0.1 in. (0.254 cm.) nor more than 0.3 in. (0.762 cm.). The thickness shall be uniform to ±5 per cent, and the surfaces shall be smooth and free from irregularities. Other thicknesses may be used where it is desired to test materials of the various thicknesses in commercial use. In any case, the capacitance of the specimen shall preferably not be less than 100 micro-microfarads.

(*b*) *Films.*—For testing films of insulating varnish, lacquer, or paints, the test specimen shall be prepared as specified for the dielectric strength tests in Appendix II to the Tentative Methods of Testing Varnishes Used for Electrical Insulation (A.S.T.M. Designation: D 115 - 35 T) of the American Society for Testing Materials.[1] The copper or brass plate shall be one capacitor plate, and tin-foil the other. Both varnish films may be tested individually.

(*c*) *Tubes.*—For testing rolled or molded laminated tubes, or ceramic tubes the test specimen shall have the diameter and wall thickness of the material it represents, and shall be of sufficient length to provide a capacitance of not less than 100 micro-microfarads. The thickness shall be uniform to ± 5 per cent, and the surfaces shall be smooth and free from irregularities.

Conditioning of Test Specimens. 9. Before the specimens are tested, they shall be kept for 48 hours under uniform atmospheric conditions. Unless otherwise specified, these conditions shall be a relative humidity of 60 per cent and a temperature of 20 to 30 C. A satisfactory method of maintaining constant humidity is given in Section 13 of the Standard Methods of Test for Resistivity of Insulating Materials (A.S.T.M. Designation: D 257) of the American Society for Testing Materials.[2]

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[1] See p. 1084.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 1107.

Electrodes.

10. (*a*) *Molded or Sheet Materials.*—The electrodes shall consist of tin or lead-foil disks 4.5 in. (11.43 cm.) in diameter and approximately 0.001 in. or 0.002 in. (0.025 or 0.050 mm.) in thickness. They shall be applied to the surface of the specimen and shall be accurately centered with respect to each other and approximately with respect to the specimen. A very thin coating of petrolatum shall be used as an adhesive.

(*b*) *Films.*—For testing materials of thickness less than 0.1 in. (0.254 cm.), such as thin-sheet insulating materials and films of insulating varnish and lacquer, the electrode area may be adjusted to give any convenient capacitance above 100 micro-microfarads. When calculating the dielectric constant of such materials, the edge correction should be omitted.

(*c*) *Tubes.*—The outer electrode shall consist of tin or lead foil. The inner electrode shall consist either of tin or lead foil, or of mercury. The electrodes shall completely cover the tube surfaces to within $\frac{1}{4}$ in. of the ends of the specimen, shall be centered approximately with respect to the length of the specimen, and shall be located exactly opposite each other.

NOTE 1.—A very thin coating of petrolatum is a good adhesive for the foil. A cork or a wax plug provides means for holding the mercury in the tube.

NOTE 2.—*Test Cell for Insulating Oils.*—A cell that has been found suitable for power factor and dielectric constant measurements of ordinary insulating oils is described in the Appendix.

Measurements at Other than Room Temperature.

11. It is frequently desirable to measure the losses in materials at temperatures other than room temperature. In order to do this the apparatus for holding the specimen may be placed within an oven for elevated temperatures and a refrigerator for lower temperatures. In either case the temperature shall be controlled accurately. Proper care shall be exercised in carrying the leads from the bridge to the specimen so that they are properly insulated and shielded.

NOTE.—It is desirable to measure the humidity at all temperatures. Humidity may cause changes as large or larger than those caused by temperature.

PROCEDURE AT FREQUENCIES IN THE ORDER OF 100 TO 1500 KILOCYCLES

Method.

12. (*a*) The method of measurement may be either the Substitution Method as described in Sections 13 to 16, or the Bridge Method as described in Sections 17 to 21.

Measurements.

(*b*) The power factor and dielectric constant of at least two specimens shall be measured at such frequencies as may be mutually agreed upon between the supplier and the purchaser. Unless otherwise agreed upon the frequencies shall be approximately 100 kilocycles and 1000 kilocycles.

A. Substitution Method

APPARATUS

Generating Circuit.

13. *Oscillator.*—The generating circuit for the Substitution Method shall consist of an oscillator (preferably a vacuum tube) which is the power source. This oscillator shall be designed so as to be easily adjustable over a range of frequencies from 100 to 1500 kilocycles, and shall have a power rating sufficient to prevent any reaction on frequency or voltage output when coupled to the measuring circuit. The oscillator output shall be of approximately sine-wave form, having not more than 5 per cent harmonic components. The oscillator shall be well shielded. The entire apparatus shall be installed in a well-shielded room or so located as to be free from interference.

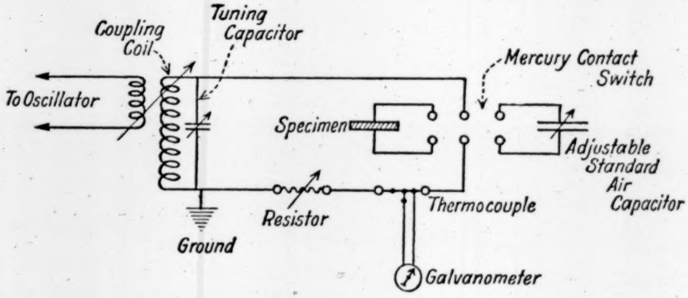


FIG. 6.—Measuring Circuit Diagram for Determination of Power Factor and Dielectric Constant by the Substitution Method.

Measuring Circuit.

14. The measuring circuit is shown in Fig. 6 and shall consist of the following parts:

Coupling Coils.—Several coupling coils so designed as to tune over the required frequency range to within 1 per cent of the frequency desired. For convenience in tuning, an adjustable air capacitor of about 0.001 micro-farads capacity (tuning capacitor) may be connected across the coupling coil. This tuning capacitor should be of the same sensitivity of adjustment as the standard air capacitor, but no calibration is necessary.

Capacitor.—An adjustable standard air capacitor having a capacitance of about 0.001 microfarad capable of being read to 0.5 micromicrofarad. This capacitor shall be calibrated for capacitance and power factor over the required frequency range.

Switch.—A special high-frequency switch of the mercury contact type having mercury cups mounted on Pyrex or quartz tubes 4 to 6 in. (10 to 15 cm.) in length. This switch shall be a double-pole, double-throw, with copper switch blades well amalgamated with mercury.

Thermocouple Galvanometer.—The thermocouple shall have a low heater resistance, preferably less than 2 ohms, and be sufficiently sensitive for use with a suitable galvanometer. The galvanometer shall be of low resistance and short period and shall be operated critically damped. It shall have a sensitivity of approximately 120 mm. per micro-ampere at a scale distance of 1 meter.

Resistors.—Several resistors made of short, straight lengths of non-magnetic resistance wire (advance or manganin is preferable) sealed into glass tubes (which may be evacuated if desired). These resistors shall all have approximately the same length. For most work, 30 resistors to cover a range of 0.2 to 60 ohms will suffice. When resistance values higher than 60 ohms are required, a 3-dial 1000-ohm non-reactive decade box may be used.

METHOD

Operation.

15. (*a*) *Procedure.*—With the specimen connected to the measuring circuit through the mercury contact switch, the circuit shall be tuned to approximately the desired frequency by proper selection of the coupling coil. The circuit may be brought into exact resonance by adjusting the frequency of the oscillator, or by means of the tuning capacitor if the latter is used. Resonance is indicated by maximum deflection of the galvanometer. The coupling to the oscillator shall be varied at the same time so that with no resistance inserted in the measuring circuit, approximately a two-third scale deflection of the galvanometer is obtained.

The adjustable standard air capacitor and a resistor shall then be substituted for the specimen. The resistance should be so chosen that when the measuring circuit is tuned to resonance by adjusting the standard air capacitor, a maximum deflection will be obtained on the galvanometer which is approximately the same as that previously produced by the specimen. Four resistors shall then be chosen having resistance values such that when inserted in the circuit, two will give deflections above and two below the deflection produced by the specimen. The deflections obtained with these four resistors shall be plotted against their resistance values. From this curve the equivalent series resistance *R* of the specimen shall be obtained by reading the value of resistance corresponding to the deflection produced by the specimen and adding to it the value of the resistance of the standard capacitor at the capacitance and test frequency used.

When a decade resistor is used, the procedure is the same as above except that it is sufficient to adjust the resistor to obtain a deflection equal to that produced by the specimen. The equivalent series resistance R is then equal to the dial reading of the resistance box plus the resistance of the standard air capacitor at the capacitance and test frequency used.

The capacitance reading of the standard air capacitor corrected for lead capacitance is the equivalent series capacitance C of the specimen.

The frequency shall be determined after the final tuning.

(*b*) *Alternative Procedure.*—The circuit for the alternative substitution method is shown in Fig. 7 and consists of a coupling coil, capacitor, switch, thermocouple galvanometer, and resistors as for the Substitution Method and conforming to the requirements of Section 14.

The standard capacitor shall be tuned to resonance, first, with the specimen in parallel and then alone in the circuit. The manipulation and calculations shall be made as follows: With the resistance R, set to zero and the specimen, C_x, in parallel with the adjustable standard air capacitator, C_s, tune C_s to resonance, read the value of C_s (equals C_1) and the galvanometer deflection d_1. Disconnect the specimen and tune C_s to resonance and read (equals C_2), add resistance R_1, to make galvanometer deflection equivalent to d_1, calculate C_x and R_x from the following formulas:

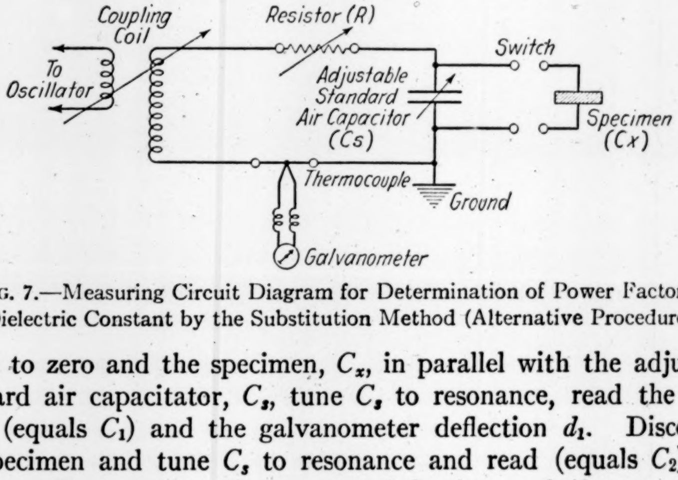


FIG. 7.—Measuring Circuit Diagram for Determination of Power Factor and Dielectric Constant by the Substitution Method (Alternative Procedure).

$$C_x = C_2 - C_1$$

$$R_x = R_1 \left(\frac{C_2}{C_x}\right)^2$$

The power factor shall be calculated from the following formula:

$$\text{Power Factor} = 2\,\pi f\, C_x\, R_x$$

where f is expressed in cycles, C_x is expressed in farads and R_x is expressed in ohms.

Calculations. 16. Calculations for power factor shall be made as described in Section 5 (*a*). Calculations for dielectric constant and loss factor shall be made as described in Sections 6 and 7, respectively.

B. Bridge Method

APPARATUS

Generating Circuit.

17. The generating circuit for the Bridge Method shall be the same as for the Substitution Method as described in Section 13.

NOTE.—The oscillator does not need to be of as high a power output for the Bridge Method as for the Substitution Method.

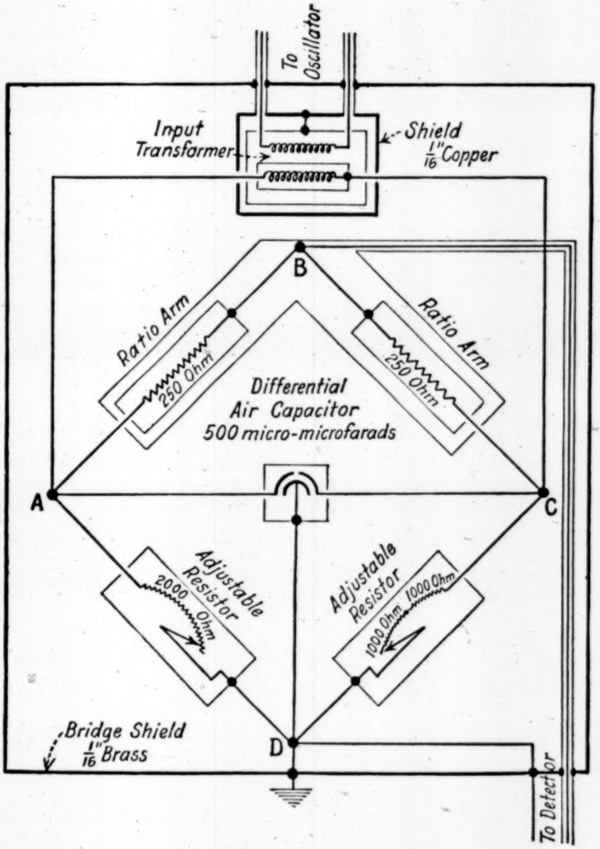

To Oscillator
Input Transformer
Shield $\frac{1}{16}$" Copper
B
Ratio Arm
250 Ohm
Ratio Arm
250 Ohm
Differential Air Capacitor 500 micro-microfarads
A
C
Adjustable Resistor
2000 Ohm
Adjustable Resistor
1000 Ohm
1000 Ohm
Bridge Shield $\frac{1}{16}$" Brass
D
To Detector

FIG. 8.—Measuring Circuit Diagram for Determination of Power Factor and Dielectric Constant by the Bridge Method.

Measuring Circuit.

18. The measuring circuit is shown in Fig. 8 with necessary shielding as indicated, and shall consist of the following parts:

Balanced Resistors.—One pair of balanced non-reactive resistors or ratio arms, *AB* and *BC*, each of approximately 250 ohms resistance, and enclosed in an electrostatic shield as shown in Fig. 8. These arms shall be balanced for resistance to within 0.05 of 1 per cent, and for reactance to within 0.1-micro-microfarad equivalent parallel capacitance.

Adjustable Resistors.—Two non-reactive adjustable resistors each shielded as shown, for use in the *AD* and *CD* arms of the bridge. The *CD* arm resistor shall comprise two 1000-ohm steps. The *AD* arm resistor shall be a four-dial decade box having steps of 0.1, 1, 10, and 100 ohms, with an additional 1000-ohm step. Precision type, high-frequency commercial resistances are satisfactory for use in these resistors.

Differential Air Capacitor.—One differential air capacitor of 500-micro-microfarad capacitance, total variation. For convenience it is desirable to provide a vernier capacitor adjustable to 0.01 micro-microfarad. These capacitors shall be calibrated to read the capacitance inserted in the *CD* arm.

Input Transformer.—One shielded input transformer[1] adapted to the connection of a 250-ohm impedance to the oscillator.

Detector Circuit. 19. The detector circuit shall consist of any suitable detector of sufficient sensitivity to indicate an unbalance of 0.1 ohm in the *AD* bridge arm. A heterodyne type used with a telephone receiver will be found satisfactory.

METHOD

Operation. 20. Suitable leads for connecting to the specimen shall be connected to terminals *C* and *D* of the bridge, Fig. 8, but not to the specimen. The bridge shall then be balanced by adjusting the differential air capacitor and the adjustable arm resistor *AD*. The capacitance and resistance values are then recorded as C_o and R_o. These readings shall be taken to compensate for the capacitance in the bridge and lead wires. The specimen shall then be connected to the lead wires, and the bridge balanced again. The capacitance and resistance values are recorded as C_1 and R_1. The equivalent parallel capacitance of the specimen is: $C_p = C_1 - C_o$, and the conductance $G = \frac{R_o - R_1}{R_o \times R_1}$. By properly adjusting the value of R_o, G can be made substantially equal to $R_o - R_1$ times some power of ten.

The frequency shall be determined when the bridge is finally balanced.

Calculations. 21. Calculations for power factor shall be made as described in Section 5 (*b*). Calculations for dielectric constant and loss factor shall be made as described in Sections 6 and 7, respectively.

---

[1] For general features of such a transformer, see "A Shielded Bridge for Inductive Impedance Measurements at Speech and Carrier Frequencies," by W. J. Shackelton, *Journal*, Am. Inst. Electrical Engrs., February, 1927, p. 159.

ACCURACY

Accuracy.

22. The accuracy of the power factor and dielectric constant determinations by the above methods depend critically upon the care exercised in setting up the measuring equipment and in its subsequent manipulation. The technique exercised in these respects shall be such that an accuracy within ±10 per cent for the determination of power factor, within ±5 per cent for the determination of the dielectric constant of sheets, and within ±10 per cent for the determination of the dielectric constant of tubes shall be obtained.

REPORT

Report.

23. The report shall include the following:

(*a*) The power factor, the dielectric constant, and the loss factor of each specimen.

(*b*) The following values for the specimen: the capacitance of the specimen in micro-microfarads; effective area of the specimen; and the average thickness of the specimen between electrodes.

(*c*) The following test conditions: the frequency in kilocycles; temperature of the atmosphere in degrees Centigrade; relative humidity of the atmosphere in per cent; and the conditioning of the specimen (hours at humidity and temperature).

(*d*) A description of the material: that is, the name, grade, and color, and the name of the manufacturer.

(*e*) Method of measurement.

PROCEDURE AT FREQUENCIES IN THE ORDER OF 1000 CYCLES

Method.

24. (*a*) The method of measurement shall be the bridge method and may be any one of those described in Sections 25 to 28. Slight modifications of any one of these methods may be used with equally satisfactory results.

(*b*) The power factor and dielectric constant of at least two specimens shall be measured at such frequencies as may be mutually agreed upon. Unless otherwise specified, the frequency shall be 1000 cycles.

APPARATUS

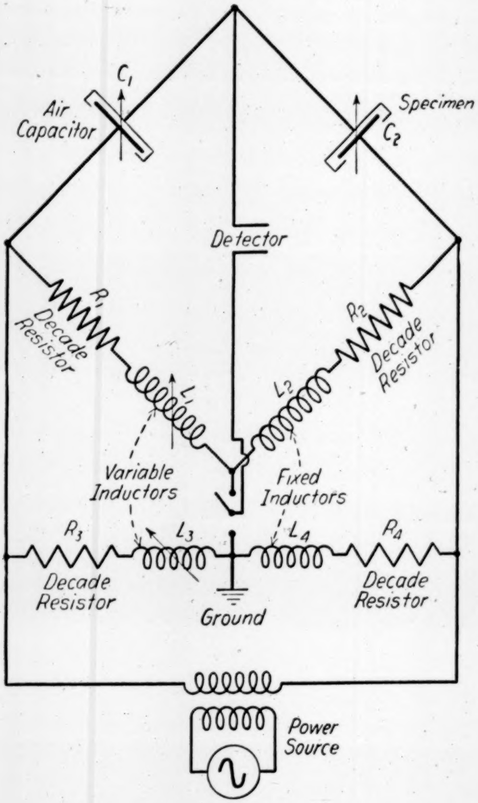
Generating Circuit.

25. *Power Source.*—The generating circuit may be a vacuum tube oscillator, a motor driven generator, or a tuning fork or other satisfactory source of 1000 cycles. The source shall be of approximately sine-wave form, having not more than 5 per cent harmonic components.

Measuring Circuit.

26. Satisfactory measuring circuits, shown in Figs. 9, 10 and 11, are as follows:

(*a*) Figure 9 shows a measuring circuit where C_1 is an auxiliary air capacitor of about 4500 micro-microfarads, C_2 is the specimen being measured or a standard air capacitor. R_1, R_2, R_3, and R_4 are decade resistors. L_1 and L_3 are variable inductors each having a maximum of 12 millihenries and a minimum of 3 millihenries inductance; L_2 and L_4 are fixed inductors each of 11 millihenries. For power factors of less than 0.05 the resistance of the combinations $R_1 + L_1$, $R_2 + L_2$, $R_3 + L_3$ and $R_4 + L_4$ shall be 1000 ohms. For power factors greater than 0.05 these resistances shall be 500 ohms. The capacitance of the test specimen should be between 1000 and 3500 micro-microfarads. For this circuit very satisfactory results have been obtained without increasing the shielding over that built into



C_1
Air Capacitor
Specimen
C_2
Detector
R_1
Decade Resistor
R_2
Decade Resistor
L_1
L_2
Variable Inductors
Fixed Inductors
R_3
L_3
L_4
R_4
Decade Resistor
Ground
Decade Resistor
Power Source

FIG. 9.—Bridge Measuring Circuit for Determination of Power Factor and Dielectric Constant at Frequencies in the Order of 1000 Cycles.

the air capacitors. A 1000-cycle generator giving about 55 volts on the specimen may be used in this set-up as a source of power.

(*b*) Figure 10 shows a measuring circuit where R_1 and R_2 are each 5000 ohms. C_1 is a standard air capacitor, C_s is a standard balancing capacitor of at least 1000 micro-microfarads and C_x is the test specimen. R_3 is a balancing variable resistor of 11,110 ohms which may be thrown in either arm of the bridge containing capacitors. One dial of 0.1 ohm is desirable in this resistor. This set-up may be used satisfactory with any of the following sources of power: a tuning fork, a vacuum tube oscillator and a 1000-cycle generator. The capacitance of the test specimen shall be not less than 100 micro-microfarads. The entire bridge proper is shielded except the leads to the capacitors and the specimen. It has been found desirable to enclose the entire set-up with exception of the oscillator and the detecting device in an earthed metal box.

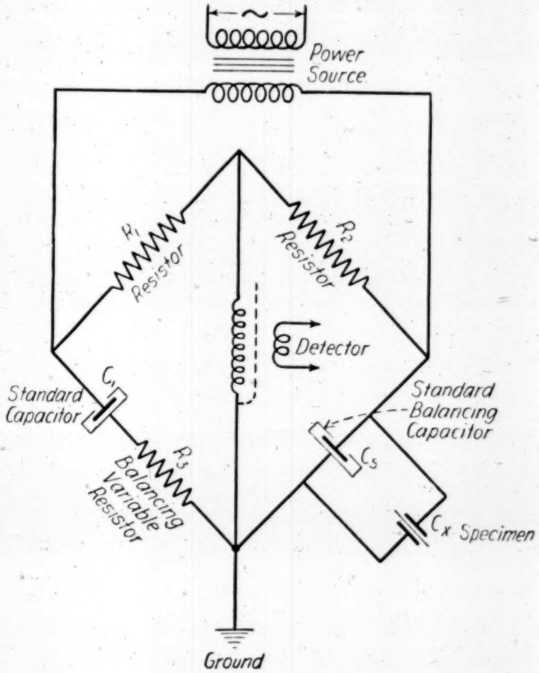
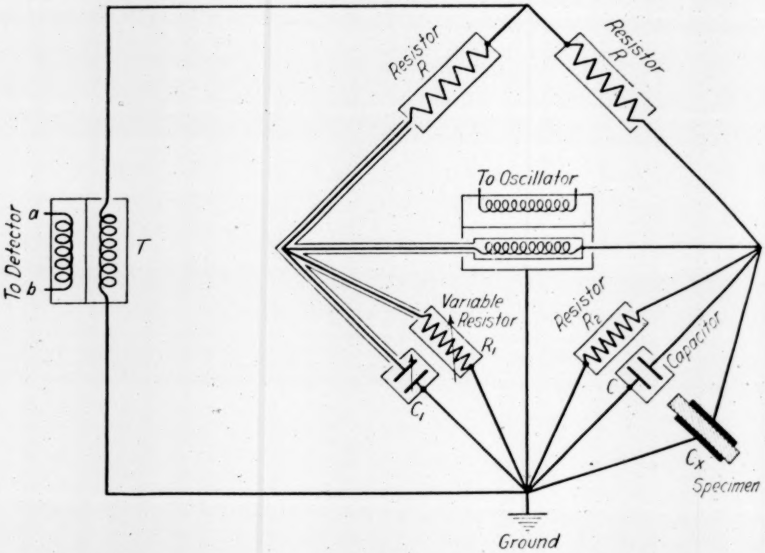

Power Source
R_1 Resistor
R_2 Resistor
Detector
Standard Capacitor C_1
Standard Balancing Capacitor
C_s
R_3 Balancing Variable Resistor
C_x Specimen
Ground

FIG. 10.—Bridge Measuring Circuit for Determination of Power Factor and Dielectric Constant at Frequencies in the Order of 1000 Cycles.

(*c*) Figure 11 shows a measuring circuit in which the two (ratio) arms each contain a resistance, R, of 1000 ohms; R_2 is 10,000 ohms; R_1 is a variable resistor from 0 to 10,000 ohms in steps of 0.01 ohm;

C_x is the test specimen; C is a variable air condenser, the maximum value of which need not exceed 200 micro-microfarads and the calibration of which need not be known; C_1 is a variable standard air condenser with a maximum capacitance greater than the maximum value of $C_x + C$. An oscillator may be used with this set-up which gives about 3 to 8 volts across the specimen. The method is suitable for measurements on test specimens as low as 50 micro-microfarads. It has been found desirable to entirely shield the set-up except for the leads to the test specimen.

NOTE.—Transformer, *T*, Fig. 11, is not necessary if one terminal of the detector may be grounded at *a* or *b*, and with rare exceptions this may be done. The resistors should be specially selected for use in alternating currents of relatively high frequency.



R Resistors, fixed, 1000 ohms each
R_1 Resistor, variable, 10,000 ohms
R_2 Resistor, fixed, 10,000 ohms
C Capacitor, variable, 200 micro-microfarads maximum
C_1 Capacitor, variable, capacity greater than $C + C_x$
C_x Test specimen
T Detector Transformer

FIG. 11.—Bridge Measuring Circuit for Determination of Power Factor and Dielectric Constant at Frequencies in the Order of 1000 Cycles.

Detector Circuit. 27. The detector circuit shall consist of any suitable detector, head phones, string galvanometer, etc., which has a sufficient sensitivity to give values of the power factor accurate to ± 5 per cent.

METHOD

Operation. 28. The procedure in making the measurements shall be such as to enable the operator to determine the capacitance of the test specimen and also its equivalent resistance. The actual manipulation in this regard will depend upon the exact circuit chosen.

Calculation.

29. (*a*) *Power Factor.*—The calculation of the power factor shall be made as described in Section 5 (*a*) and (*b*) with proper modifications as given in the following paragraphs in order to conform to the particular set-up used:

When the measuring circuit described in Section 26 (*a*), Fig. 9, is used, the formula for calculation of the power factor reduces to the following:

$$\text{Power factor} = 2\,\pi\,f\,\frac{(L_2 - L_1)}{R_1}$$

Where L_2 and L_1 are in henries, R_1 is in ohms, and f is in cycles.

When the measuring circuit described in Section 26 (*b*), Fig. 10, is used, the formula for calculation of the power factor is as follows:

$$\text{Power factor} = 2\pi f C_x R_x \times 10^{-12}$$

where C_x = difference in capacitance of the standard capacitor with specimen in and out;

f = the frequency in cycles;

$R_x = (R' - R)\,\dfrac{C'^{\,2}_s}{C_x^{\,2}}$, where

R' = value of R_3 with specimen out;
R = value of R_3 with specimen in;
C'_s = capacitance of the standard capacitor with specimen out;
C_s = capacitance of the standard capacitor with specimen in;
$C_x = C'_s - C_s$

All values of capacitance in micro-microfarads; resistance is in ohms.

When the measuring circuit described in Section 26 (*c*), Fig. 11, is used, the formula for calculation of the power factor is as follows:

$$\text{Power factor} = \frac{G \times 10^{12}}{2\pi f C_p}$$

where G = the conductance of specimen in mhos calculated as follows:

$$G = \frac{R' - R}{R' \times R}$$

where R' = resistance R_1 with specimen out; and
R = resistance of R_1 with specimen in.

f = the frequency in cycles

C_p = the capacitance of the specimen calculated from the equation: $C_p = C'_s - C_s$

C'_s = capacitance of the standard C_1 with specimen in, and
C_s = capacitance of C_1 with specimen out.

All values of capacitance in micro-microfarads; resistance is in ohms.

(*b*) *Dielectric Constant.*—The calculation of the dielectric constant shall be made as described in Section 6.

(*c*) *Loss Factor.*—The calculation of the loss factor shall be made as described in Section 7.

REPORT

Report.

30. The report shall include the following:

(*a*) The power factor, the dielectric constant, and the loss factor of each specimen.

(*b*) The following values for the specimen: the capacitance of the specimen in micro-microfarads; effective area of the specimen; and the average thickness of the specimen between electrodes.

(*c*) The following test conditions: the frequency in cycles; temperature of the atmosphere in degrees Centigrade; relative humidity of the atmosphere in per cent; and the conditioning of the specimen (hours at humidity and temperature).

(*d*) A description of the material: that is, the name, grade, and color, and the name of the manufacturer.

(*e*) Method of measurement.

PROCEDURE AT COMMERCIAL FREQUENCIES IN THE ORDER OF 25 TO 60 CYCLES

Method.

31. (*a*) The method of measurement shall be the bridge method and may be one of those described in Section 32. Modifications of these methods may be used with equally satisfactory results.

(*b*) The power factor and dielectric constant of at least two specimens shall be measured at such frequencies as may be mutually agreed upon between the manufacturer and the purchaser. Unless otherwise specified, the frequency shall be 60 cycles.

APPARATUS

Generating Circuit.

32. *Power Source.*—The generating circuit or source of power may be any 25 to 60-cycle source, depending upon the frequency agreed upon, which shall be of approximately sine wave form, and not have more than 5 per cent harmonic components.

Measuring Circuit.

33. Satisfactory measuring circuits, shown in Figs. 12 and 13, are as follows:

(*a*) *Parallel Resistance and Capacitance Bridge.*—Figure 12 shows a measuring circuit of the parallel resistance and capacitance bridge type.

The resistors *R* in the arms *AB* and *BC* are each 10,000 ohms.

R_1 is a 111,100-ohm decade resistance box.

R_2 is a 100,000-ohm fixed resistor.

S is a shielded input transformer.

T is a shielded output transformer.

C_1 and C_2 are precision air capacitors of 1000 or 1500 micromicrofarads capacitance.

C_x is the specimen capacitance.

R_x is the equivalent resistance of the specimen.

A suitable detector to be used at *T* is a vacuum tube voltmeter. Preliminary settings may be obtained even by the use of headphones and the final balance secured with the voltmeter.

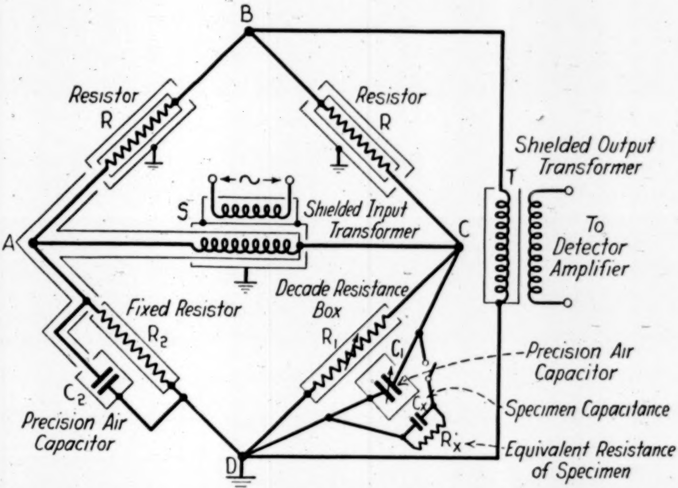

B
Resistor
R
Resistor
R
Shielded Output Transformer
T
S
Shielded Input Transformer
A
C
To Detector Amplifier
Decade Resistance Box
Fixed Resistor
R2
R1
C1
Precision Air Capacitor
Cx
Specimen Capacitance
C2
Precision Air Capacitor
Rx
Equivalent Resistance of Specimen
D

FIG. 12.—Parallel Resistance and Capacitance Bridge for Measurements at 60 to 1000 Cycles per Second.

Any combination of amplifier with indicator, or an a.c. galvanometer combination which has sensitivity to give measurements of power factor accurate to ±5 per cent will be satisfactory.

(*b*) *Schering Bridge.*—Figure 13 shows a measuring circuit of the Schering bridge type.

A and *B* are the measuring points of the bridge.

C and *D* are the input points of the bridge.

C_1 is the specimen under test.

C_2 is a guarded air capacitor.

R_3 and R_4 are non-inductive resistors which are variable to 10,000 ohms.

C_3 is ordinarily the residual capacitance of the bridge arm. It

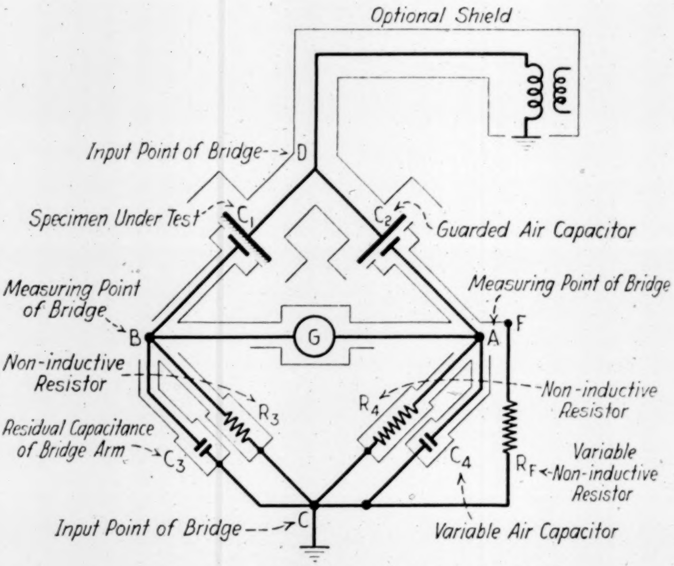

Optional Shield
Input Point of Bridge
D
Specimen Under Test
C1
C2
Guarded Air Capacitor
Measuring Point of Bridge
Measuring Point of Bridge
B
G
A
F
Non-inductive Resistor
R3
R4
Non-inductive Resistor
Residual Capacitance of Bridge Arm
C3
C4
Variable Non-inductive Resistor
RF
Input Point of Bridge
C
Variable Air Capacitor

FIG. 13.—Schematic Diagram for Schering Bridge.

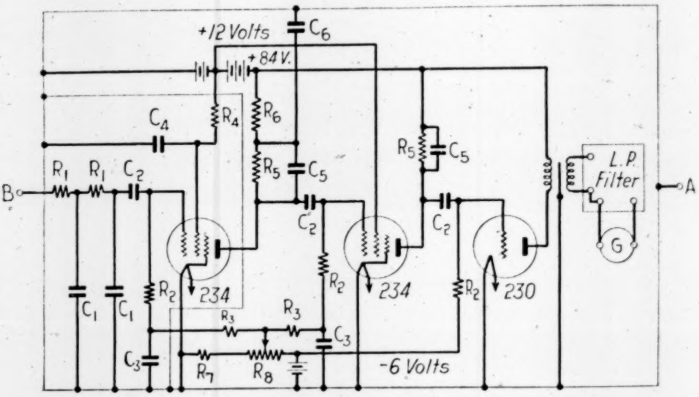

+12 Volts
C6
+84 V.
C4
R4
R6
R5
C5
R5
C5
B
R1
R1
C2
C2
C2
L.P. Filter
A
G
234
234
230
R2
R2
R2
C1
C1
R3
R3
C3
C3
R7
R8
-6 Volts

FIG. 14.—Schematic Diagram for Schering Bridge Amplifier and Galvanometer

If the amplifier is to be used from 25 to 60 cycles, suitable resistance and capacitance are:

RESISTANCE	
R_1	**10 000 ohms**
R_2	**2 megohms**
R_3	**0.25 megohms**
R_4	**20 000 ohms**
R_5	**0.2 megohms**
R_6	**50 000 ohms**
R_7	**1 000 ohms**
R_8	**20 000 ohms**

CAPACITANCE	
C_1	0.01 μf.
C_2	0.05 μf.
C_3	1 μf.
C_4	4 μf.
C_5	0.01 μf.
C_6	1 μf.

Three 22½-volt "B" batteries of the smallest size and one 22½-volt tapped "C" battery provide plate, screen and grid bias voltages, 84, 12 and −6 volts, respectively.

may be necessary to introduce a small additional capacitance at C_3 when measuring specimens with very small losses.

C_4 is a variable air capacitor of 1000 or 1500 micro-microfarads capacitance. For measuring larger values of power factor an additional capacitor may be shunted across C_4.

R_F is a variable non-inductive resistor of 10,000 ohms. In case it should be found desirable to balance for phase as well as for magnitude, a suitable capacitor should be placed in parallel with R_F.

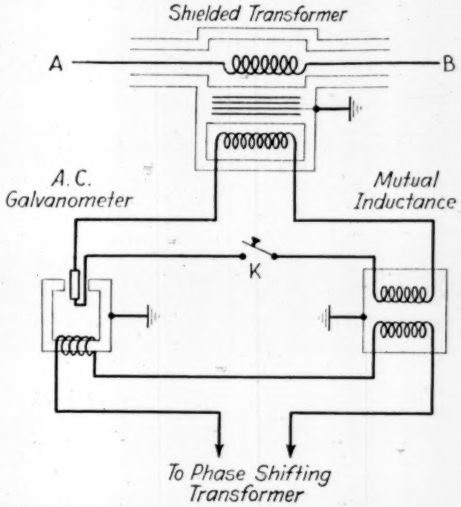


FIG. 15.—Schematic Diagram for Schering Bridge Galvanometer.

The detector for the measuring circuit shown in Fig. 13 may have various forms.

A resistance coupled amplifier that has been found satisfactory as a detector is shown in Fig. 14. This is placed across the bridge at the points A, B, Fig. 13. At the output of such an amplifier, a low pass filter and a microammeter with a copper oxide rectifier may be used.

Another detector consists of a sensitive a.c. galvanometer in combination with a mutual inductance and phase shifter for balancing, as shown in Fig. 15. For preliminary balances or for relatively large loss specimens, use may be made of a vibration galvanometer, or a string galvanometer having reasonable sensitivity.

METHOD

34. The procedure in making the determinations shall be such as to enable the operator to determine the capacitance of the test speci- **Operation.**

men and also its equivalent resistance. The exact manipulation will depend upon the circuit and the detector chosen.

Calculation. 35. (*a*) *Power Factor.*—The calculation of the power factor shall be made as described in Section 5 (*a*) and (*b*) with the proper modifications as given in the following Paragraphs (*b*) and (*c*) in order to conform to the circuit used:

(*b*) *Parallel Resistance and Capacitance Bridge.*—When the measuring circuit described in Section 32 (*a*) and shown in Fig. 12 is used, the formulas for the calculation of the power factor reduce to the following:

$$\text{Power factor} = \cos\theta$$

$$\cot\theta = \frac{1}{2\pi f C_x R_x}$$

where R_X = the resistance of the specimen in ohms and is given by the expression:

$$R_x = \frac{R_1 R'_1}{R'_1 - R_1}$$

R_1 = the resistance of R_1 with the specimen out.
R'_1 = the resistance of R_1 with the specimen in place.

f = the frequency in cycles.
C_x = the capacitance of the specimen and equals $C_1 - C'_1$.

C_1 = the capacitance with the specimen out.
C'_1 = the capacitance with the specimen in place.

In these expressions, all the capacitances are in farads and the resistances are in ohms.

NOTE.—If the power factor is less than 0.1, it may be calculated by the following approximation with not over 0.5 per cent error:

$$\text{Power factor} = \frac{1}{2\pi f C_x R_x}$$

(*c*) *Schering Bridge.*—When the measuring circuit described in Section 32 (*b*) and shown in Fig. 13 is used, the power factor shall be calculated by the following formula:

$$\text{Power factor} = \cos\theta = \cos(\alpha - \beta)$$

where α and β are defined by the following equations:

$$\text{Cot}\,\alpha = 2\pi f C_4 R_4$$
$$\text{Cot}\,\beta = 2\pi f C_3 R_3$$

f = the frequency in cycles.
C_3 and C_4 are in farads.
R_3 and R_4 are in ohms.

NOTE.—Usually C_3R_3 may be made negligibly small in comparison with C_4R_4, in which case the following approximations hold:

$$\text{Power factor} = \cos\theta$$
$$\cot\theta = 2\pi f C_4 R_4$$

If, in addition, the power factor is less than 0.1, then

$$\text{Power factor} = 2\pi f C_4 R_4$$

The equivalent parallel capacitance of the specimen, C_p, is most conveniently calculated from the equivalent series capacitance, C_1, as follows:

$$C_1 = C_2\frac{R_4}{R_3}$$

$$C_p = \frac{C_1}{1 + \cot^2\theta}$$

θ is defined in Figs. 2 and 4.

C_2, R_3, and R_4 are defined in Fig. 13.

(*d*) *Dielectric Constant.*—The calculation of the dielectric constant shall be made as described in Section 6. If a guarded specimen is used no edge correction will be necessary but proper consideration shall be given only to the real area of the shielded electrode.

(*e*) *Loss Factor.*—The loss factor shall be calculated as described in Section 7.

REPORT

36. The report shall include the following: **Report.**

(*a*) The power factor, the dielectric constant, and the loss factor of the specimen.

(*b*) The following values for the specimen: the capacitance of the specimen in micro-microfarads, the effective area of the specimen, and the average thickness of the specimen between the electrodes.

(*c*) The following test conditions: the frequency in cycles, the temperature of the specimen during test in degrees Centigrade, the relative humidity as a percentage of the atmosphere surrounding the specimen, the conditioning of the specimen, the voltage gradient and the kind of electrodes.

(*d*) A description of the material; that is, the name, grade, color, and the name of the manufacturer.

(*e*) The method of measurement.

APPENDIX

CELL FOR POWER FACTOR AND DIELECTRIC CONSTANT MEASUREMENTS OF ORDINARY INSULATING OILS

A cell that has been found suitable for the purpose of measuring the power factor and dielectric constant of oil (and solid filling and treating compounds) is shown in Appendix IV of the Tentative Methods of Testing Solid Filling and Treating Compounds Used for Electrical Insulation (A.S.T.M. Designation: D 176 - 35 T) of the American Society for Testing Materials.[1] The cell is suitable for the common types of insulating oils but oils of extra high quality would require that the insulation be entirely out of the field. The power factor of insulation in this cell shall be of at least the same order as the power factor of the oil to be tested. In addition, the insulation must be chosen so that it will not be appreciably affected by the oil or cleaning solvents and must not absorb sufficiently to electrically contaminate subsequent test samples.

This cell has the following points of simplicity and efficiency:

1. Ease of insulating electrodes.
2. Large area of electrodes in compact form, the outer one of which serves as a container. This outer electrode is also exposed directly to the heating medium and aids in rapid changes from one temperature to another and also promotes uniform temperature in the comparatively thin layer of oil in contact with it.

3. Comparative ease in assembling and disassembling the cell and in cleaning.

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[1] See p. 1006.

TENTATIVE METHODS OF TESTING SHEET AND PLATE MATERIALS USED IN ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 229 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1925; REVISED, 1926, 1928, 1930, 1931, 1932, 1934, 1935.

Scope. 1. These methods are intended to apply to stiff, flat sheet and plate materials, such as phenolic and other types of laminated sheets, vulcanized fiber, hard rubber, asbestos composition board, etc., to be used as electrical insulation.

Definition of Terms. 2. In referring to the cutting of the specimens and the application of the load, the following definitions apply:

Flatwise.—Load applied to the flat side of the original sheet or plate.

Edgewise.—Load applied to the edge of the original sheet or plate.

Lengthwise.—In the direction of the length of the sheet.

Crosswise.—In the direction at right angles to the length of the sheet.

NOTE.—When the sheet has the same length and width, one dimension shall arbitrarily be designated as the length, and the other as the width.

TENSILE STRENGTH

Apparatus. 3. Any standard type of testing machine may be used. The machine shall be accurate to within 1 per cent on the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned.

Specimens. 4. Tension test specimens shall conform to the dimensions shown in Fig. 1. The surfaces of the specimen shall be smooth and free from scratches.

Procedure. 5. Five specimens cut lengthwise and five specimens cut crosswise of the sheet shall be tested.

Temperature. 6. All tests shall be made at normal room temperature of about 20° C. (68° F.).

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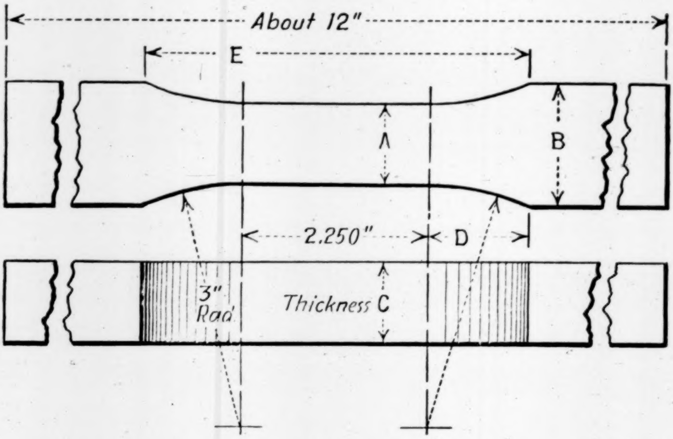
[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

Speed of Testing Machine. 7. The cross-head speed of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

Modulus of Elasticity. 8. When it is desired to determine the elongation under load, a suitable extensometer measuring the elongation on a 2-in. gage length shall be used. The cross-head speed of the testing machine shall not exceed 0.03 in. per minute when the machine is running idle.

Procedure. 9. The total change in length between zero load and a stress of 5000 lb. per sq. in. shall be determined.



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in., D is 0.857", E is 3.964 in.
When C is $\frac{1}{8}$ in. or over, A is 1 in., B is $1\frac{1}{2}$ in., D is 1.199", E is 4.648 in.

FIG. 1.—Tension Test Specimen for Laminated Sheet Insulating Materials.

Report. 10. The report shall include the following:

(*a*) The direction in which the specimen was taken, whether lengthwise or crosswise of the sheet.

(*b*) The thickness and width of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm.

(*c*) The breaking load of each specimen, in pounds or kilograms.

(*d*) The tensile strength of each specimen, in pounds per square inch or in kilograms per square centimeter.

(*e*) The location and nature of the fracture.

(*f*) The elongation in inches at a stress of 5000 lb. per sq. in., if determined.

(*g*) The room temperature.

FLEXURAL STRENGTH

(FORMERLY CALLED TRANSVERSE STRENGTH)

(*A*) *For Materials $\frac{1}{32}$ in. or Over in Thickness*[1]

Apparatus

11. (*a*) Any standard type of testing machine may be used. The machine shall have an accuracy of at least 1 per cent of the lowest load for which it is used.

(*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. for material $\frac{1}{8}$ in. or over in thickness, and to a radius of $\frac{1}{16}$ in. for thinner materials. For material thinner than $\frac{1}{8}$ in. both supports shall be provided with a pin or other stop to align one side of the specimen perpendicular to the line of contact with the supports. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction, except that the minimum span shall be $\frac{1}{2}$ in.

Specimen.

12. The test specimen shall be $\frac{1}{2}$ in. in width except for specimens over $\frac{1}{2}$ in. in thickness tested in the flatwise direction, which shall have the width equal to the thickness of the specimen. The thickness shall be the full thickness of the sheet. The length shall be 1 in. greater than the distance between the points of support as specified in Section 11 (*b*).

Procedure.

13. The specimens shall be tested as follows:

(*a*) Five specimens cut lengthwise of sheet, tested flatwise.

(*b*) Five specimens cut lengthwise of sheet, tested edgewise.

(*c*) Five specimens cut crosswise of sheet, tested flatwise.

(*d*) Five specimens cut crosswise of sheet, tested edgewise.

Temperature of Tests.

14. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine.

15. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report.

16. The report shall include the following:

(*a*) The directions of cutting and loading of the specimen as specified in Section 13.

(*b*) The thickness and width of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm.

(*c*) The breaking load of each specimen in pounds or kilograms.

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[1] Conventional flexure tests in a flatwise direction are not recommended for materials thinner than $\frac{1}{32}$ in. nor in the edgewise direction for materials thinner than $\frac{1}{4}$ in.

(*d*) The maximum fiber stress in pounds per square inch or kilograms per square centimeter calculated from the formula:

$$S = \frac{3}{2}\frac{Pl}{bd^2}$$

where S = maximum fiber stress;
P = breaking load in pounds or kilograms;
l = distance between supports in inches or centimeters;
b = width of specimen in inches or centimeters;
d = depth of specimen in inches or centimeters.

(*e*) The room temperature.

COMPRESSIVE STRENGTH

Apparatus. 17. Any standard testing machine may be used provided it is accurate within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable, at the top, and the metal bearing plates shall be directly in contact with the ends of the test specimen.

Specimen. 18. (*a*) For sheets 1 in. in thickness or over, the test specimen shall be a 1-in. cube, the faces of which shall be flat and perpendicular to the axes, being ground to this condition if necessary.

(*b*) For sheets less than 1 in. in thickness, the specimen shall consist of a pile of sheets 1 in. square with a minimum number of layers to produce a height of at least 1 in.

Procedure. 19. (*a*) For sheets 1 in. in thickness or over, three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.

(*b*) For sheets less than 1 in. in thickness, three specimens shall be crushed in the condition in which they are received with the load applied flatwise of the sheet.

20. The load shall be applied on the ends of the specimen and the crosshead speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 in. (1.27 mm.) per minute when the machine is running idle. For the best results use the slowest possible speed.

Report. 21. The report shall include the following:

(*a*) The dimensions of each specimen in inches expressed to the nearest 0.001 in. or in centimeters expressed to the nearest 0.025 mm

(*b*) The direction of application of the load;

(*c*) The load on each specimen in pounds or kilograms at the first sign of failure;

(*d*) The ultimate compressive strength in pounds per square inch or kilograms per square millimeter, of each specimen, calculated from the area of each specimen measured before the load is applied;

(*e*) The general character of the material tested; with a description of how it acts under the applied load.

Resistance to Impact. 22. (*a*) Resistance to impact shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (A.S.T.M. Designation: D 256 - 34 T) of the American Society for Testing Materials.[1]

Specimen. (*b*) Specimens for the Charpy test may be notched or unnotched, as desired, according to conditions of service, and for the Izod test shall be notched. Specimens shall be cut both lengthwise and crosswise of the sheet.

NOTE.—The unnotched specimen gives a higher strength than the notched specimen and the ratio of the strength of the unnotched specimen to that of the notched specimen varies with different materials.

WATER ABSORPTION TESTS

Scope. 23. The water absorption tests are intended to determine the rate at which water is absorbed by the material when immersed, the total quantity absorbed at saturation, and the volatile content as received.

NOTE.—The electrical properties of different materials are not necessarily affected to the same extent by the same increase in moisture content so that the water absorption test must be correlated with the desired electrical tests.

The water immersion test and exposure to air of high humidity are not always directly comparable and should be considered before substituting one for the other.

(*A*) *Rate of Absorption*

Specimen. 24. The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches to the nearest 0.001 in. shall be measured on the original specimen at the center.

Procedure. 25. To determine the rate of absorption, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately re-weighed. The difference between the original weight and the dry weight shall be recorded as loss in weight on drying. The percentage loss in weight shall be calculated on the original weight.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 995 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 993.

(*b*) The dried specimen shall then be immersed in distilled water maintained at a temperature of 25° C. ± 2° C. (77° F. ± 3.6° F.) throughout the test. At the end of 2 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens the test shall be repeated.

Report. 26. The report shall include the values for each of the two specimens and the average values as follows:

(*a*) The thickness of the specimen before the test, to the nearest 0.001 in.;

(*b*) The percentage loss in weight on drying calculated on the original weight;

(*c*) The percentage of water absorbed in 2 hours and in 24 hours calculated on the dry weight.

(*B*) *Total Absorption at Saturation*

Specimen. 27. (*a*) The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches measured to the nearest 0.001 in. shall be measured on the original specimen at the center and on the reduced specimen in case a reduced specimen is used (see Paragraph (*b*)).

(*b*) When the sample for determining total absorption is so thick that too long a time is required for saturation using the full thickness, the thickness may be reduced as follows: The sample shall be machined to a thickness of about $\frac{5}{64}$ in., both surfaces parallel to the laminations being machined off. This may readily be done with a smooth-cut circular saw. It shall then be sanded to $\frac{1}{16}$ in. in thickness, finishing with No. 0 or finer sandpaper. While the sanded surfaces of the sample should be approximately parallel with the laminations, the thickness may vary ±0.010 in., since the object is to provide comparable specimens which will reach saturation in a reasonable time. The machined and sanded sample shall then be cut into specimens 3 by 1 in. and the edges sanded.

Procedure.

28. To determine the total water absorption at saturation, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately reweighed. The difference between the original weight and the dry weight shall be recorded as loss of weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 24 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. The weighings shall be repeated every day for the first week and every week thereafter until the increase in weight, as shown by three consecutive weighings, averages less than 1 per cent of the total increase in weight, when the specimen shall be considered to be saturated.

(*c*) The difference between the saturated weight and that of the dry weight shall be considered as the water absorbed at saturation. The percentage of water absorbed shall be calculated on the dry weight of the specimen.

Report.

29. This report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of material, measured to the nearest 0.001 in.;

(*b*) If a reduced specimen is used, the thickness measured to the nearest 0.001 in.;

(*c*) The percentage loss in weight on drying, calculated on the original weight;

(*d*) The percentage of water absorbed at saturation, calculated on the dry weight.

(*C*) *Volatile Matter*

Specimen. 30. The test specimen shall conform to the requirements specified in Section 12.

Procedure. 31. To determine the volatile matter, two specimens shall be tested individually as follows:

The specimen shall be weighed, dried in an oven at from 105 to 110° C. until the decrease in weight as shown by two consecutive weighings at least 24 hours apart is less than 1 per cent of the total decrease in weight. The difference between the original weight and the dry weight shall be recorded as the volatile matter present in the specimen as received (this includes in addition to water any volatile solvent left during manufacture). The percentage of volatile matter shall be based on the weight of the dry specimen.

Report. 32. The report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of the material measured to the nearest 0.001 in.;

(*b*) The percentage of volatile matter, based on the weight of the dry specimen.

DIELECTRIC STRENGTH

Dielectric Strength. 33. The dielectric strength shall be determined in accordance with the Tentative Methods of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 - 34 T) of the American Society for Testing Materials.[1]

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Dielectric Constant. 34. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant (A.S.T.M. Designation: D 150 - 35 T) of the American Society for Testing Materials.[2]

BONDING STRENGTH

For Laminated Materials $\frac{3}{16}$ in. or Over in Thickness

Apparatus. 35. Any standard type of testing machine may be used, providing it is accurate within 1 per cent of the lowest load for which it is used. To this shall be fitted a head containing a 10-mm. steel ball.

Specimens. 36. Test specimens shall be 1 in. square, smoothly and accurately cut on a smooth saw.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 982 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 980.

[2] See p. 1044.

Procedure. 37. Five specimens shall be tested. These shall be placed on edge and the steel ball shall center accurately between the edges and ends of the specimen.

Temperature. 38. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine. 39. The speed of the cross-head of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report. 40. The report shall include the following:

(*a*) the thickness of the material; and

(*b*) the load, expressed in pounds or kilograms, required to split the specimen.

ROCKWELL HARDNESS

Apparatus. 41. (*a*) The Rockwell hardness tester shall be used, conforming to the requirements of the Tentative Methods of Rockwell Hardness Testing of Metallic Materials (A.S.T.M. Designation: E 18 – 33 T) of the American Society for Testing Materials.[1]

(*b*) The hardness shall be determined using a $\frac{1}{4}$-in. diameter ball penetrator, a minor load of 10 kg. and a major load of 100 kg., the readings being taken on the black figures.

Specimen. 42. (*a*) The specimen shall have a minimum thickness of $\frac{1}{4}$ in. The specimen may be composed of a pile-up of several pieces of the material of the same thickness, providing that precaution is taken that the surfaces of the pieces are in contact and not held apart by burrs from saw cuts, etc. The area of the specimen shall be 1 in. square if cut from sheet stock or other shape of at least this area.

(*b*) Care shall be taken that the test is not made so near the edge of the specimen that it will break out when the major load is applied.

(*c*) The specimen shall be supported in such a manner as to prevent errors due to overhang, when it does not balance itself on the anvil.

(*d*) All tests shall be made at normal room temperature of about 20° C. (68° F.).

NOTE.—It should be noted that some materials such as laminated phenolic plates show an appreciable variation in the Rockwell hardness with variation in temperature as small as 8° C. (15° F.).

Procedure. 43. The procedure outlined in the Tentative Methods E 18 – 33 T[1] shall be followed. The adjustment of speed of load application and the time of application of the major load are of great importance. The machine shall be so adjusted that the major load will be fully applied in from 6 to 8 seconds as a longer time will give an erroneous result due to "creeping" of some materials.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 967 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 1377.

Report. 44. The report shall include the following:

(*a*) The Rockwell hardness number read on the black scale, the major load and the diameter of the penetrator;

(*b*) The total thickness of the specimen;

(*c*) The number of pieces in a specimen and their average thickness, and

(*d*) The room temperature.

TENTATIVE METHODS OF TESTING SHELLAC USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 411 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Scope

1. These methods cover tests for shellac in the dry or powdered form to be used for electrical insulating purposes.

Sampling and Chemical Tests

General Tests

2. Each of the following tests shall be made in accordance with the methods described in the Standard Methods of Sampling and Testing Shellac (A.S.T.M. Designation: D 29) of the American Society for Testing Materials:[2]

(*a*) Sampling.
(*b*) Insoluble Matter.
(*c*) Iodine Number.
(*d*) Moisture Content.
(*e*) Wax (Method *B*).
(*f*) Ash.

Polymerization Time

Apparatus

3. The apparatus required for the test for polymerization time shall consist of the following:

(*a*) *Test Tubes.*—Two $\frac{3}{4}$-in. glass[3] test tubes, supported by a wire rack to a depth of 4 in. when placed in an oil bath. It is essential that the test tubes be supported and maintained in a vertical position. The rack shall be so constructed as to permit free circulation of oil around the test tubes.

(*b*) *Oil Bath.*—An oil bath of such construction as to permit of maintaining a uniform test temperature within 1 C. It is essential to use a mechanical stirring device in the oil bath to maintain a uniformly distributed temperature. The oil used shall be a mineral oil having a Saybolt Universal viscosity of approximately 150 sec. at 100 C.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] 1933 Book of A.S.T.M. Standards, Part II, p. 678.

[3] Pyrex or quartz glass is satisfactory for this purpose.

(*c*) *Burner.*—A bunsen burner for heating the oil bath.

(*d*) *Glass Rod.*—A smooth glass rod 5 mm. in diameter. A small mark or indicator shall be placed on top of the rod or the glass formed-over to facilitate readings as outlined in Section 6 (*d*). The sides of the glass rod, near the end which is immersed in the shellac, shall be flattened slightly.

(*e*) *Thermometer.*—A suitable thermometer to indicate the test temperature.

Conditioning

4. (*a*) Samples of shellac before testing shall be rolled and mixed well on clean paper and then carefully dried as described in Paragraph (*b*).

(*b*) A flat-bottomed dish, about 4 in. in diameter containing a 5-g. sample of shellac, shall be placed in a well-ventilated gas or electric oven at a temperature of 41 C. ± 2 C. for approximately 16 hr. (or overnight). It is essential to have the sample spread out on the dish during the drying period.

(*c*) After drying, the sample shall be transferred immediately to a clean, dry bottle, and stoppered tightly, allowing it to cool in the bottle. The bottle shall not be opened except when a specimen is being removed for test.

Specimen

5. (*a*) Each specimen shall consist of 2 g. of the shellac taken from the stoppered bottle.

(*b*) Two specimens of each shellac sample shall be tested.

Procedure

6. (*a*) A specimen of shellac shall be transferred from the stoppered bottle to the $\frac{3}{4}$-in. glass test tube. The tube shall then be inserted and held securely in a vertical position in the test rack placed in the oil bath maintained at the specified test temperature. The temperature shall be maintained throughout the test within ±1 C. of the desired temperature.

NOTE.—The method is suitable for testing at any temperature between 125 and 225 C.

(*b*) The time when the test tube enters the oil bath shall be recorded.

(*c*) Using the 5-mm. glass rod, the specimen shall be stirred gently for the first 3 min. of the test so that the shellac becomes well melted in as short a time as possible. It is essential that there be no stirring after the first 3-min. period.

(*d*) At the end of each minute thereafter the glass rod shall be given a slight twist (turning approximately 90 deg.). In the early stages of the test, and before the polymerization point is reached, the glass rod will remain in the position to which it has been turned. When, however, the shellac takes on a rubbery set, there will be a definite turning or twisting back of the rod following the 90-deg. twist. This is the endpoint. (In the early stages of the test there may be a tendency for the glass rod to move back slowly after twisting with the fingers. This slight movement should not be confused with the definite "twist-back" observed when the endpoint is reached.)

(*e*) The temperature shall be recorded each minute during the test. The average of all these readings shall be considered the test temperature.

Polymerization Time

7. The elapsed time in minutes, from the time of entry into the bath and including the 3-min. stirring period, until the first "twist-back" of the glass rod is noted, shall be recorded as the "polymerization time."

Report

8. The report shall include the following:

(*a*) The polymerization time to the nearest minute for each specimen.

(*b*) The average of the values in Paragraph (*a*).

(*c*) The test temperature.

TENTATIVE METHODS OF TESTING FLEXIBLE VARNISHED TUBING USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 350 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1935.

Scope

1. These methods cover the testing of flexible varnished tubing (Note) used as electrical insulation for leads on electrical apparatus.

NOTE.—The term "varnished tubing" as here used refers to braided cotton sleeving coated, or impregnated and coated with lacquer or a combination of lacquer and varnish or other similar coatings.

SAMPLING

Sampling

2. (*a*) A sufficient number of the pieces of tubing to total not less than 1.83 m. (6 ft.) in length shall be selected from each 305 m. (1000 ft.) in the shipment, but in no case shall less than 1.83 m. (6 ft.) be taken from a shipment and the pieces shall be selected in such a manner as to be representative of the shipment.

(*b*) The number of specimens required for purpose of tests shall be cut from the pieces selected in accordance with Paragraph (*a*) and care shall be taken to select material which is free from abnormal defects such as blisters, wrinkles, cracks, etc.

CONDITIONING

Conditioning

3. Specimens shall be conditioned for at least 2 hr. in air maintained at a temperature between the limits of 20 and 30 C. (68 and 86 F.), before testing.

DIMENSIONS

Apparatus

4. (*a*) Standard gage rods and a 1-in. machinist's type micrometer with ratchet device and having anvil and spindle surfaces 0.25 in. ± 0.001 in. in diameter shall be used.

(*b*) The standard gage rods shall be steel and shall have smooth surfaces. A set of two is required for each size of tubing. Each rod in a set shall have a diameter within ± 0.0002 in. of the diameters listed as maximum and minimum in the following table:

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

A.S.T.M. STANDARD SIZES FOR FLEXIBLE VARNISHED TUBING.

	INSIDE DIAMETER, IN.				INSIDE DIAMETER, IN.		
SIZE	MAXIMUM	MINIMUM	NOMINAL	SIZE	MAXIMUM	MINIMUM	NOMINAL
1	0.299	0.289	0.294	10	0.110	0.102	0.106
2	0.268	0.258	0.263	11	0.099	0.091	0.095
3	0.239	0.229	0.234	12	0.089	0.081	0.085
4	0.212	0.204	0.208	13	0.080	0.072	0.076
5	0.190	0.182	0.186	14	0.068	0.064	0.066
6	0.170	0.162	0.166	15	0.061	0.057	0.059
7	0.152	0.144	0.148	16	0.055	0.051	0.053
8	0.137	0.129	0.133	17	0.049	0.045	0.047
9	0.122	0.114	0.118	18	0.044	0.040	0.042

Specimens

5. Specimens of any convenient length shall be cut from the samples as obtained in Section 2.

Procedure

6. The largest size gage rod that will fit the tubing without stretching it shall be inserted into the tubing and shall be the measure of the inside diameter of the tubing. While the tubing is on the rod, outside diameter measurements shall be taken at distances 2 in. apart until five readings are obtained. The outside diameter of the tubing shall be the average of these five readings.

NOTE.—The procedure in using the micrometer for measuring the outside diameter shall conform to Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 34 T) of the American Society for Testing Materials.[1]

Report

7. The report shall include the inside diameter and the average, maximum, and minimum outside diameters in inches.

DIELECTRIC STRENGTH

Test Procedure

8. The dielectric strength of the tubing shall be determined in accordance with the short-time dielectric strength test as described in Sections 2 and 9 of the Tentative Methods of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 – 34 T) of the American Society for Testing Materials.[1]

Specimens and Electrodes

9. (*a*) A straight standard annealed copper wire shall serve as the inner electrode in a specimen of convenient length. The nearest A.w.g. size of

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 1069, 982 (1934); also 1935 Book of A.S.T.M. Tentative Standards, pp. 1087, 980.

wire shall be selected which will fit snugly without stretching the tubing. The wire shall be free of bends to avoid a binding action on the tubing as it is being slipped onto the wire. After the tubing has been placed on the copper wire, strips of metal foil 2.54 cm. (1 in.) wide shall be tightly wrapped on the outside at a distance of not less than 7.62 cm. (3 in.) apart and at least 7.62 cm. (3 in.) from the ends of the specimen.

(*b*) The metal foil shall have a thickness not to exceed 0.0005 in. and the first turn of the foil applied to the tubing shall be wiped snugly against the tubing. Two more turns of the foil shall then be wound over this first turn, leaving a free end of ½ in. to which the electrical connection shall be made during the test.

NOTE.—The standard gage rods should never be used as the inner electrode. The arc which forms when the tubing punctures will invariably raise a pimple of melted metal on the surface of the rod, spoiling it for use as a standard.

Test Conditions

10. (*a*) The test voltage shall be applied between the copper wire and each metal foil strip in turn.

(*b*) The tests shall be made in air with the specimen at room temperature.

(*c*) The dielectric strength shall be the average of ten puncturing voltages.

Report

11. The report shall include the following:

(*a*) Total volts at each puncture.
(*b*) The average, maximum, and minimum puncturing voltages.
(*c*) The room temperature.
(*d*) The relative humidity, in per cent.

HEAT ENDURANCE

Specimens

12. Not less than ten specimens, each 15.24 cm. (6 in.) in length shall be cut from the samples.

NOTE.—If the heat endurance is in excess of 120 hr., additional specimens will have to be cut.

Procedure

13. The specimens shall be placed in a uniformly heated electric oven of the analytical type in which the temperature is maintained between the limits of 105 and 110 C. (221 and 230 F.). Two specimens shall be removed at the end of 24 hr. and every 24 hr. thereafter until failure occurs. After cooling to room temperature of approximately 20 C. (68 F.), each specimen shall be bent through 180 deg. over a rod 0.32 cm. (⅛ in.) in diameter. The number of hours of baking at which first cracking across the specimen occurs shall be noted and reported.

RATE OF BURNING

(In the case of non-flammable or flame-resistant tubing)

Apparatus

14. The apparatus required for the rate of burning test shall be a bunsen burner, a stop watch, and a suitable support for holding the specimen.

Specimens

15. At least three specimens 9.16 cm. (4 in.) in length shall be cut from the samples as obtained in Section 2.

Procedure

16. (*a*) A gage length of 2.54 cm. (1 in.) shall be marked on the test specimen at least 2.54 cm. (1 in.) from the end of the specimen. The specimen shall be held mechanically in a horizontal position in still air.

(*b*) The flame of the bunsen burner shall be applied to the unsupported end of the specimen until the specimen ignites. The flame shall then be removed and the time in seconds for the leading edge of the flame to travel over the gage length of 2.54 cm. (1 in.) shall be observed with the stop watch.

NOTE.—Any metal rod inserted into the specimen for convenience in holding the specimen must not enter the region spanned by the gage length.

(*c*) The rate of burning shall be defined as the number of seconds required to burn a length of 2.54 cm. (1 in.) of the specimen.

Report

17. The rate of burning for each specimen shall be reported.

TENTATIVE METHODS OF TESTING VARNISHES USED FOR ELECTRICAL INSULATION[1]

A.S.T.M. Designation: D 115 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1921; REVISED, 1922, 1923, 1924, 1925, 1926, 1928, 1929, 1930, 1931, 1934, 1935.

Scope

1. These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.

SPECIFIC GRAVITY

Specific Gravity

2. The specific gravity shall be measured with a pycnometer, Westphal balance or with a hydrometer so graduated that the specific gravity can be determined to 0.001. The temperature of the varnish shall be not less than 18° C. (64.4° F.) nor more than 22° C. (71.6° F.) and corrected to 20° C. (68° F.) by applying a correction of 0.0007 per 1° C. (0.0004 per 1° F.).

VISCOSITY

Viscosity

3. (*a*) The viscosity shall be determined at 20° C. (68° F.) and the results shall be stated in terms of absolute viscosity—poise[2] or centipoise (centipoise = 0.01 poise).

(*b*) Viscosimeters used in this test shall be calibrated with oils certified as to viscosity in absolute units by the National Bureau of Standards. A calibration curve having viscosities in absolute units as ordinates and instrument readings as abscissas and covering the range of viscosities to be measured, shall be used.

NOTE.—A description of the MacMichael viscosimeter as remodeled and miproved for varnish testing together with directions for its calibration in absolute units appears in Appendix I.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-9 on Electrical Insulating Materials.

[2] The absolute viscosity of a material or its viscosity in absolute units (c.g.s., poises) has been defined as the force in dynes required to move, at a velocity of 1 cm. per second, one surface having an area of 1 sq cm. past another parallel like surface 1 cm. away, overcoming the resistance to shear of the material filling the space between.

FLASH POINT

Flash Point

4. The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids (A.S.T.M. Designation: D 56) of the American Society for Testing Materials.[1]

TIME OF DRYING

Test Specimens

5. (*a*) Specimens for this test shall be pieces of thoroughly cleaned, smooth sheet copper or brass about 4 cm. (1.57 in.) wide and 20 cm. (7.88 in.) long and about 0.127 mm. (0.005 in.) thick.

(*b*) The specimen shall be dipped once in the varnish at a room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The consistency of the varnish shall be first so adjusted by trial that, when dry as determined in accordance with Section 7, the average thickness of the film of varnish on each side of the metal shall be between 0.022 and 0.026 mm. (0.0009 and 0.001 in.) Care shall be taken before dipping the specimens that the varnish has stood in the dipping tank for a sufficient length of time to be free from air bubbles.

Procedure

6. (*a*) Specimens of air-drying varnish shall be dried in dust-free air at a room temperature of approximately 20° C. (68° F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain at a room temperature of approximately 20° C. (68° F.) until the varnish is set as indicated when the impression left on the surface by pressing lightly thereon with a finger at a point approximately 2 in. from the bottom will not become obliterated by further flow of the material. They are then to be dried in dust-free air in an oven at 105 to 110° C. (221 to 230° F.). At the end of the first 30 minutes, and again at the end of each 10-minute period thereafter, one specimen shall be taken from the oven and examined. In the case of slow-drying varnishes, this 10-minute period may be lengthened at the discretion of the operator.

NOTE.—The size of oven and the amount of ventilation have a considerable effect on the drying time of varnishes. For this reason the analytical type of electrically-heated oven should be used.

Time of Drying

7. The varnish shall be considered dry when a piece of kraft paper 38 mm. (1.49 in.) in width and 152 mm. (6 in.) in length and approximately 0.063 mm. (0.0025 in.) in thickness does not adhere to the

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 663.

varnish when it is pressed on the surface of the varnish for one minute by a cylindrical 1-lb. weight, 1 in. in diameter. The kraft paper shall be applied in the vicinity of the center of the specimen and at right angles to it. The test shall be made at a temperature of approximately 20° C. (68° F.).

NOTE.—Certain types of varnishes dry with what is commonly known as a "tack"; but these types are rare. However, when testing them for drying time, it will be found that the kraft paper adheres to the varnish film and offers a certain amount of resistance to removal. On continued drying, the resistance to removal reaches constancy and is not changed by further drying. Therefore, the drying time is reported as the number of hours required to first reach constancy and the varnish should be reported as drying with a "tack."

DIELECTRIC STRENGTH TEST[1]

Scope

8. (*a*) This test is intended to determine the suitability of an insulating varnish for use in certain electrical applications by taking the dielectric strength test under different conditions of temperature and after immersion in water. The test provides for the determination of dielectric strength under the following conditions:

(*1*) At room temperature (approximately 20° C.) in air.

(*2*) At 75° C. in air.

(*3*) At room temperature after immersion in water of approximately 20° C. (68° F.) for a period of 24 hours.

NOTE.—Dielectric strength determinations may also be made at room temperature and at 75° C. in oil. With this exception the procedure for test is the same as outlined here. If tests are made in oil this fact must be definitely reported with the results.

(*b*) Much more information about a varnish can be obtained by making the test under all three conditions than by making it under only one condition. The relation which the dielectric strength tests for a given varnish show to one another, is of quite as much significance as the values for the different tests considered separately.

Test Specimens

9. (*a*) Specimens for the dielectric strength test shall be prepared by dipping pieces of kraft paper about 20 cm. (7.88 in.) square and about 0.076 mm. (0.003 in.) in thickness into the varnish which shall be at the consistency specified in Section 5 (*b*).

NOTE.—The paper used shall be that which is commercially known as No. 1 sulfate kraft. The surface of the paper shall be smooth, free from pimples or lumps and reasonably free from hairy fibers. The paper shall also be free from conducting particles, slime spots, creases, cuts, specks or other "paper defects."

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[1] This test is relative only, but it gives more uniform results than those obtained with a copper base. See Appendix II for a procedure for determining the dielectric strength on a copper base, p. 1103.

(*b*) Each specimen shall be dipped twice, as specified in Section 5 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in dust-free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period six times that determined in accordance with Section 7.

(*d*) Specimens of baking varnish shall be drained and then baked in dust-free air at a temperature of 105 to 110° C. (221 to 230° F.) after each dip for a period three times that determined in accordance with Section 7.

(*e*) The final thickness of the specimen shall be 0.152 mm. (0.006 in.) to within ± 15 per cent.

Procedure

10. (*a*) The dielectric strength of the specimen shall be determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage shall be increased at a rate of approximately 0.5 kv. per second. The electrodes shall be polished and cleaned after each puncture. As the temperature of the electrodes increases after a number of tests, it is advisable to change the electrodes after every twenty punctures. Ten such punctures are to be made at various points selected at random on each specimen. After testing, the thickness of the specimen shall be determined by making five measurements on a strip cut diagonally across the specimen. The measurements shall be equally spaced along the strip except in the case of a measurement being too close to a point of puncture. The average of the five measurements shall be considered as the thickness of the specimen.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined by the American Institute of Electrical Engineers,[1] and the voltage shall be measured by methods approved by the same organization.

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 100 volts. The apparatus shall comply with the standards of the American Institute of Electrical Engineers.[1]

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[1] Standards of the American Institute of Electrical Engineers.

Test Conditions

11. The dielectric strength shall be determined under the following conditions:

(*a*) At room temperature (approximately 20° C.) in air.

(*b*) At 75° C. in air.

NOTE.—The tests at 75° C. shall be made in air in an analytical type of electrically-heated oven. The electrodes shall be at oven temperature before the test is started. Tests should be started 15 minutes after the specimen has been introduced into the oven and placed between the electrodes and completed before 15 minutes additional have elapsed.

(*c*) At room temperature on specimens which shall have been immersed in water at a room temperature of approximately 20° C. (68° F.) for a period of 24 hours.

NOTE 1.—In testing specimens after immersion in water, only one specimen should be removed from the water at a time. The specimen after removal from the water should be carefully dried by placing between sheets of dry blotting paper and pressing down gently with the hand over the entire surface. If necessary, the blotting procedure should be repeated until the specimen is free from surface moisture. The specimen should then be tested immediately. If specimens are allowed to remain out of water for even a short time before testing, they dry out to a greater or less extent and the test is apt to be misleading.

NOTE 2.—Dielectric strength determinations may also be made at room temperature and at 75° C. in oil. With this exception the procedure for test is the same as outlined above. If tests are made in oil this fact must be definitely reported with the results.

Report

12. In reporting the results for each of the three tests made as described in Section 11, the total voltage at puncture, the thickness of the specimen and the volts per mil of thickness shall be reported for each of the ten punctures together with the average, maximum and minimum values. In addition, the average dielectric strength in volts per mil of the test made at 75° C. and of the test made after water immersion shall be expressed as a percentage of that made at room temperature.

HEAT ENDURANCE TEST

Test Specimens

13. (*a*) Specimens shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or sheet brass about 20 cm. (7.88 in.) in length, 3 cm. (1.18 in.) in width and 0.127 mm. (0.005 in.) in thickness, into the varnish. The consistency of the varnish shall previously be adjusted by trial so that, when dry as determined in accordance with Section 7, the average thickness of the film of varnish on each side of the metal shall be between 0.022 and 0.026 mm. (0.0009 and 0.001 in.).

(*b*) Each specimen shall be dipped in the varnish at room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The varnish shall be allowed to dry in the air (if an air-drying varnish) or baked in an oven at 105 to 110° C. (221 to 230° F.) (if a baking varnish) until dry as determined in accordance with Section 7. As soon as the first coat of varnish is dry, and the specimen is at room temperature, it shall be dipped again in the varnish in the reverse direction so as to give a uniform thickness of coating. The second coat of varnish shall be allowed to dry in the same manner as the first coat. When the second coat of varnish is dry, the specimen shall be measured. The thickness of varnish on each side of the metal shall be between 0.044 and 0.052 mm. (0.00173 and 0.00205 in.).

Procedure

14. (*a*) The specimens shall be placed in a uniformly-heated oven, in which the temperature is maintained at 105 to 110° C. (221 to 230° F.). A specimen shall be removed at the end of the first 24 hours and every 24 hours thereafter.

NOTE.—Because of temperature variations between different levels in the oven, the specimen should be placed in the oven with the 8-in. dimension horizontal and the 1-in. dimension vertical. All specimens should be at the same level in the oven.

(*b*) Each specimen, after heating, shall be tested at room temperature of approximately 20° C. (68° F.) by bending it through 180 deg. around a rod 0.32 cm. (0.125 in.) in diameter.

Report

15. The number of hours of baking of the specimen which first showed cracking of the varnish film shall be reported, together with the make and type number of the oven used.

NOTE 1.—This size of oven and the amount of ventilation have a considerable effect on the heat endurance of varnish films. For this reason the analytical type of electrically-heated oven should be used.

NOTE 2.—The temperature of the oven should be held as closely as possible to the mean (107.5° C., 225.5° F.). A difference of 5° C., (9° F.) in this temperature range, when continuously maintained, has a very considerable effect (approximately 25 per cent) on the life test of a varnish.

NOTE 3.—As the "grain" of the copper influences the result of the test, the heat endurance test specimens should be prepared by cutting the copper strips parallel with the direction of rolling.

OIL PROOF TEST

Test Specimens

16. (*a*) To test for the effect of oil, the specimens shall be prepared as prescribed in Section 13 (*a*).

(*b*) The specimens shall be dipped and dried as prescribed in Section 9 (*b*), (*c*) and (*d*).

Procedure

17. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 105 to 110° C. (221 to 230° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth.

NOTE.—Incipient disintegration of the surface of the varnish may sometimes be detected by examining the oil for turbidity. If a specimen of the used oil filtered through filter paper can be distinguished from an unfiltered sample of the used oil, when the two samples in identical containers are held in front of a diffused light, the oil is turbid.

DRAINING TEST

(ALSO KNOWN AS "WORKING VISCOSITY" TEST)

Test Specimen

18. A strip of sheet copper or brass about 4 cm. (1.57 in.) wide, 35 cm. (13.78 in.) long, and 0.127 mm. (0.005 in.) thick, shall be immersed in the varnish at a room temperature of approximately 20° C. (58° F.) up to a line previously drawn across the strip 1 in. from the top. The sheet shall be withdrawn at a slow and uniform rate (about 38 cm. (15 in.) per minute), care being taken that the varnish is free from air bubbles. The specimen shall be permitted to drain thoroughly at room temperature while suspended in a vertical position. It shall then be dried or baked (according to the type of the varnish) until dry as determined in accordance with Section 7.

Measurements

19. The thickness of the specimen in mils shall be measured at points 5.1 cm. (2 in.), 17.8 cm. (7 in.) and 30.5 cm. (12 in.), respectively, from the line to which the specimen was immersed.

Report

20. The thickness of each film in mils at the three points specified in Section 19 shall be recorded. The difference between the thickness at the upper point (5.1 cm.) and that at the lower point (30.5 cm.) shall be taken as a measure of the variation in the film thickness caused by draining.

TEST FOR NON-VOLATILE MATTER BY WEIGHT

Apparatus

21. The apparatus required consists of a chemical balance, a glass thermometer having a range of 0 to 150 or 200 C. and accurate within 1 C., a constant-temperature oven of uniform temperature, a stoppered bottle and flat bottom metal drying dishes. Each metal drying dish shall have an inside diameter of approximately $2\frac{3}{4}$ in. (7 cm.) and a depth of approximately $\frac{5}{16}$ in. (8 mm.).

NOTE.—A standard single-friction tin can cover having a diameter of $2\frac{13}{16}$ in. is suitable for use as a drying dish.

Test Specimen

22. The specimen shall consist of approximately 1.5 g. (1.35 g. to 1.65 g.) of the sample of varnish taken from the shipment.

Procedure

23. (*a*) *Preparing the Specimens.*—A portion of the sample of varnish shall be placed in a stoppered bottle or weighing pipette and weighed. Approximately 1.5 g. (1.35 g. to 1.65 g.) shall be transferred from the weighed stoppered bottle to a weighed drying dish which has previously been heated for 30 min. at 135 C. and cooled in a desiccator. The stoppered bottle with the remaining contents shall be weighed again. The exact weight of the specimen transferred to the drying dish shall be determined by difference. A total of three specimens shall be prepared from the contents of the stoppered bottle.

(*b*) *Drying the Specimens.*—The specimens shall be placed in the constant temperature oven within 30 min. after preparation. The specimens shall be heated for a period of 3 hr. at the temperature designated, as follows:

Impregnating varnishes of the phenolic-resin type......	132 to 138 C.
Other types of insulating varnishes....................	105 to 110 C.

NOTE.—In a gravity type of oven which depends upon the natural circulation of air for uniformity of temperature, only one shelf must be used for supporting the specimens, and the bulb of the thermometer for indicating the temperature shall be in close proximity to the specimens.

(*c*) *Weighing the Dried Specimens.*—At the termination of the 3-hr. heating period, the specimens shall be removed to a desiccator for cooling to room temperature. Each specimen shall be weighed immediately upon removal from the desiccator.

(*d*) *Calculation.*—The ratio of the weight of the dried specimen to the weight of the specimen in the original state expressed as a percentage is the percentage of non-volatile matter by weight.

Report

24. The report shall include the following:

(*a*) The type of varnish;
(*b*) The oven temperature, and
(*c*) The percentage of non-volatile matter.

TEST FOR VOLATILE MATTER BY VOLUME

Scope

25. This test is intended to determine the volume percentage of volatile matter (solvent) in a varnish, and to afford a means of arriving at the volume composition of the varnish with respect to volatile (solvent) and non-volatile (base) constituents.

Procedure

26. (*a*) About 100 ml. of the varnish shall be distilled in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[1] The distillation shall be "qualitative" instead of "quantitative" as given in Section 9 of the Standard Method D 86; that is, it is not necessary to record the volume of distillate recovered, or the temperature of the initial boiling point or end point.

(*b*) The distillation shall be continued until a suitable end point indicates that all the volatile matter (solvent) has been distilled off.

NOTE.—In the distillation of varnishes the end point differs with the various types and compositions. In all cases, however, the rate of distillation slows down as the end point is approached; and, when the end point is reached, acrolein (formed in the decomposition of the varnish base) is evolved and may be detected by its characteristic odor.

In addition to the evolution of acrolein, the following phenomena are suitable indicators of end point:

(1) When the end point of the solvent is considerably lower than the initial boiling point of the base, the end point of the distillation is indicated by the temperature reaching a maximum and then starting to fall consistently.

(2) When the end point of the solvent and the initial boiling point of the base are too close, or overlap, the above temperature drop does not occur. The end point of the distillation is then indicated by a sudden foaming up of the residual base in the distillation flask; or, if the distillation has been accompanied by foaming, the end point is indicated by a breaking of surface tension with a consequent cessation of foaming.

Specific Gravity

27. The specific gravity of the volatile matter (solvent) recovered by distillation shall be determined in accordance with the procedure described in Section 2.

Volatile Matter by Weight

28. The difference between 100 per cent and the percentage of non-volatile matter determined in Sections 21 to 24 shall be calculated and recorded as the percentage of volatile matter by weight.

Volatile Matter by Volume

29. The percentage of volatile matter by volume shall be calculated from the formula:

$$x = \frac{AC}{B}$$

where

x = the percentage of volatile matter by volume;

A = the specific gravity of the original varnish, as determined in Section 2;

B = the specific gravity of the volatile matter (solvent) recovered by distillation, as determined in Section 27; and

C = the percentage of volatile matter by weight, as determined in Section 28.

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[1] 1935 Supplement to Book of A.S.T.M. Standards, p. 177.

Accuracy

30. With proper care and attention to detail in making this test, differences occurring between different laboratories should not exceed 2 per cent for varnishes containing solvents which have end points not over 235° C. (455° F.), and should not exceed 4 per cent when the end point of the solvent is as high as 307.2° C. (585° F.).

DIELECTRIC STRENGTH OF VARNISH IN THE LIQUID STATE

Scope

31. The purpose of the dielectric strength test of varnish in the liquid state is to insure that the varnish is free from moisture and foreign matter such as might come from unclean shipping containers.

Apparatus

32. The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Materials Used for Electrical Insulation (A.S.T.M. Designation: D 48) of the American Society for Testing Materials.[1] The test cup for holding the sample of varnish shall be made of a material having a suitable dielectric strength. It must be insoluble in and unattacked by mineral oil and gasoline and non-absorbent so far as moisture, mineral oil and gasoline are concerned. The electrodes in the test cup between which the sample is tested shall be circular disks of polished brass or copper, 1 in. in diameter and having square edges. The electrodes shall be mounted in the test cup having their axes horizontal and coincident, with a gap of 0.1 in. between their adjacent faces, and with top of electrodes about 33 mm. (1¼ in.) below the top of the cup.

Procedure

33. (*a*) The electrodes and the test cup shall be wiped clean with dry calendered tissue paper or with a clean dry chamois skin, and thoroughly rinsed with a suitable solvent such as dry benzol or redistilled carbon tetrachloride. The electrodes and test cup shall then be rinsed with some of the varnish to be tested.

(*b*) The spacing of electrodes shall be checked with a standard round gage having a diameter of 0.100 in. and the electrodes then locked in position. Care shall be taken not to touch the electrodes with the gage or in any other manner after cleaning the electrodes and cup, so as to avoid any possible contamination.

(*c*) The temperature of the varnish when tested shall be the same as that of the room, which should be between 20 and 30° C. (68 and 86° F.).

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1097.

(*d*) The sample of the varnish shall be shaken so that it will be thoroughly mixed before filling the test cup, the shaking shall be done gently to avoid the formation of bubbles.

(*e*) The cup shall be filled with varnish to a height of not less than 20 mm. (0.787 in.) above the top of the electrodes.

(*f*) The varnish shall be allowed to remain in the test cup until all air bubbles have disappeared.

(*g*) Voltage shall be applied and increased uniformly at the rate of approximately 3 kv. (r.m.s. value) per second until electrical breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

(*h*) After the breakdown and before removing the varnish from the test cup, the electrode surfaces shall be rubbed thoroughly with dry calendered tissue paper wrapped around a knife blade to provide stiffness. The test cup shall then be emptied and immediately refilled with the next filling of varnish to be tested.

(*i*) Five fillings shall be tested in conformity with the above procedure and the last filling of the cup shall drain the sample container.

Variations in Results

34. Differences as great as 15 per cent may occur between different laboratories in the results of this test. This is considered satisfactory in view of the purpose of the test.

Report

35. The report shall include the following:

(*a*) The kilovolts (r.m.s. value) at each electrical breakdown;

(*b*) The average value of the 5 breakdowns in kilovolts; and

(*c*) The mean deviation from the average value expressed as a percentage of the average breakdown value.

APPENDIX I

DESCRIPTION AND USE OF REMODELED MACMICHAEL VISCOSIMETER FOR DETERMINING VISCOSITY OF INSULATING VARNISHES

APPARATUS

The viscosity of varnishes may be determined by means of the remodeled MacMichael Viscosimeter shown in Figs. 1, 2 and 3. This instrument gives the viscosity values in terms of MacMichael degrees which are converted into absolute units of viscosity (centipoise) by means of the calibration curves of the various suspending wires.

In Fig. 1 the apparatus, consisting of the following parts, is shown unassembled:

A is the indicator by means of which the zero is adjusted and readings on scale *D* are taken.

B is the insulated wire suspension, the torsion of which measures the viscosity. The wire is fastened only at the bottom of its insulating sleeve *E'*. This is suspended by hanging it on points *P'*. (Ten wires of different size to cover various ranges of viscosities are supplied.)

C is the clamp screw which clamps the hollow spindle *E* to the sleeve *E'* which holds the torsion wire *B*.

D attached to hollow spindle *E* is the dial on which are calibrated the degrees MacMichael (300 deg. to the circumference). By means of this dial and indicator *A* the degrees deflection are determined as indicated in the method described below.

E is the hollow vertical spindle inside of which is the torsion wire sleeve *E'* which contains torsion wire *B*.

F is an oil-filled dash pot which acts as a brake to deaden oscillations and bring the suspension to rest quickly when making a determination. The dash pot swings between arm guides *F'* when the machine is assembled.

G is the brass disk which is attached to the bottom of vertical spindle *E*. Torsion wire *B* and *E'* is inserted into *E* and clamped with screw *C* and the disk *G* is then suspended in the liquid whose viscosity is being measured. Rotation of the sample cup *H* rotates the liquid and the rotating liquid exerts a certain force on the disk *G* partially rotating it and thus a torsion is produced in the wire suspension *B*, the deflection of which (or degree of torsion) is read from the scale on deflecting disk *D*.

H is the container which holds the sample. A locking device fastens it securely to *I* or *J*.

I is the water bath used for securing a uniform temperature in the liquid whose viscosity is being determined, when these viscosity measurements are desired at temperatures approximating that of the room (used on varnishes and oils).

J is the heating unit which is used in place of *I* when viscosity measurements are made at high temperatures (used on compounds).

K is the contact which carries the electric current to the heating unit cup *J*. It can be swung back when using cups *H* and *I* and when therefore electric heating is not desired.

L is the counter which indicates the revolutions per minute of the turntable *M*. A trip arrangement allows this counter to be lowered or raised, thus throwing the counter in or out of operation at will.

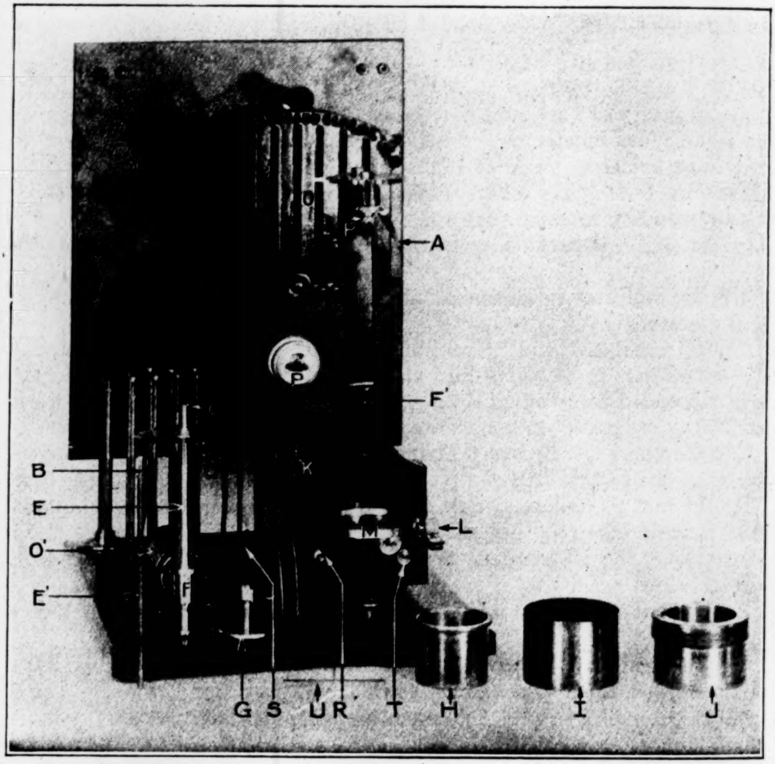

FIG. 1.—Improved MacMichael Viscosimeter Apparatus, Unassembled.

M is the rotating turntable in which *I* or *J* are set. A locking device (not shown) locks *I* or *J* securely to the turntable *M* so that when the turntable rotates the water bath or heating unit with the sample container also rotate.

N is the inclosing case under which is the motor and governor shown in Fig. 3. These operate turntable *M*.

O is a rheostat which controls the current going to the heating unit *J*.

O' is a rheostat controlling current for motor (shown only on remodeled instruments).

P is the knife switch (snap switch on new type machine) controlling the current for the heating unit *J*.

R is the push button which controls the electric current operating the motor shown in Fig. 3.

S is a leveling screw to level the instrument. Another such screw (not shown) is directly opposite to this one.

T is the governor screw that adjusts the speed of the motor by adjusting the governor shown in Fig. 3. In the remodeled apparatus the speed of rotation of turntable *M* can be decreased by moving the large gear in gear box away from the motor until pin of motor shaft is disengaged from slot of gear sleeve. The instrument is sent out with gear in low-speed position; to obtain high speeds shift gear toward motor until pin is engaged.

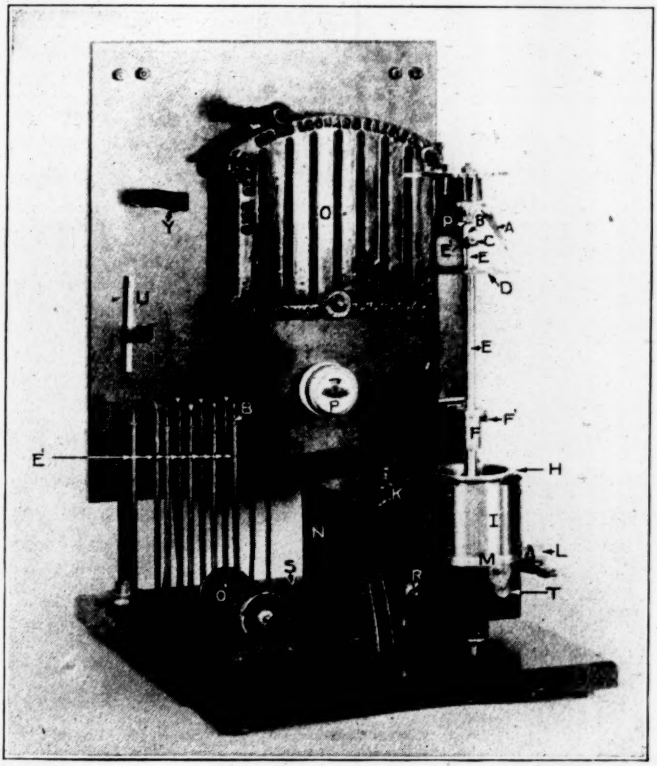

FIG. 2.—Improved MacMichael Viscosimeter Apparatus Assembled for Testing Varnish or Oil.

U is the measuring device used to measure the depth of the liquid in container *H*.

p are the projecting points on which the assembled spindle, namely, insulated torsion wire suspension *B* and *E'*, spindle and deflection dial *D*, and immersed disk *G* are suspended.

The apparatus is shown assembled in Fig. 2 for viscosity determinations on oil or varnish. Explanatory letters refer to the same parts as in Fig. 1.

In Fig. 3 are shown the internal structure and cup and heating unit assembled for testing compounds. The explanatory letters refer to the following:

V is the motor which operates the turntable *M*.

W is the governor controlling the speed of the turntable *M*.

X are the leads to connect instrument to 110-volt alternating current or direct current lighting circuit.

Y is the clamp holder for holding the spindle *E* with its dial *D*, when the machine is not in use (remodeled machines).

The heating unit *J* and the sample container, *H*, are here shown assembled as used in the viscosity determinations on compounds.

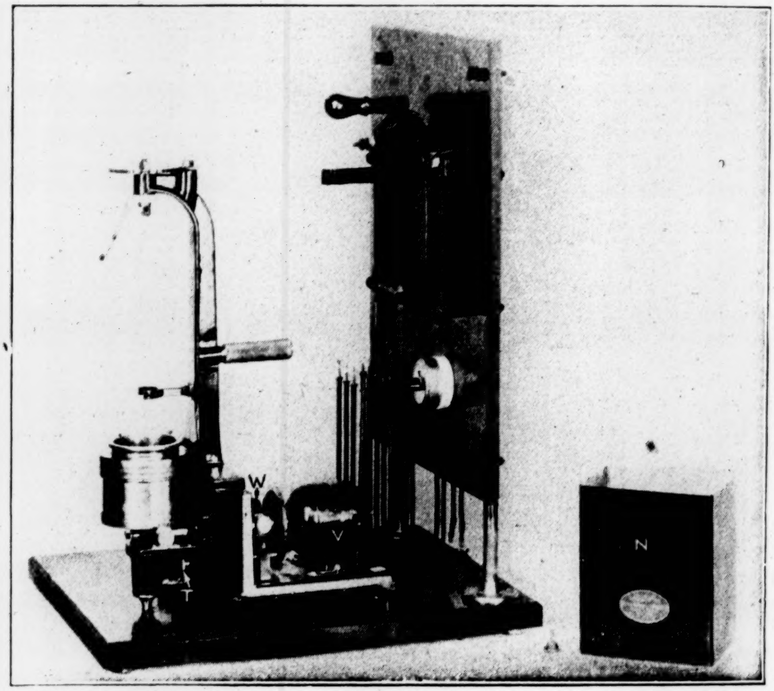

FIG. 3.—Improved MacMichael Viscosimeter Apparatus Showing Internal Structure and Cup and Heating Unit for Testing Compounds.

DIRECTIONS FOR MAKING VISCOSITY MEASUREMENTS ON VARNISH

Cups and disks must be perfectly clean. Otherwise reliable results cannot be obtained.

Dash pot *F* on the stem of the spindle should be two-thirds full of a medium grade of good machine oil (Etna Engine or Appollo) in order to dampen vibrations.

Use water bath *I* to secure and maintain the temperature of the sample in *H* when testing varnishes or oil.

Insert container *H* into water bath *I*. See that they are properly locked together, then lock bath *I* on turntable *M*.

Choose the proper torsion wire suspension for the liquid to be tested. Experience is the best guide to determine what suspension to use. Screw the disk *G* to the spindle *E*, and insert into *E* the proper insulated torsion wire suspension *E'*. Suspend these assembled parts from points *p* so the disk is suspended in the container *H*. Be sure to always suspend the wire on the points *p* with the flat side of the triangular button against the flat side of the supporting arm. The rounded surface of the triangle must face out towards the operator. Tightly fit the cover of the dash pot *F* on the arm guides F'.

See that the instrument is perfectly level. Use leveling screws *S* to adjust the instrument. The instrument is level when the suspended sleeve *E* swings exactly in the center of the hole of the cover on the dash pot.

Adjust the speed of the turntable to 60 r.p.m. This should be checked each time determinations are made. Use the governor screw *T* to adjust the speed of the motor. The gear in the gear box, referred to under *T* in the description of Fig. 1, should be in high speed position, that is, towards the motor. Use a stop watch to adjust the speed. After the speed is adjusted, lower the counter *L* so it will not operate during the following procedure.

NOTE.—The deflection is directly proportional to the speed of rotation. The 60 r.p.m. must therefore be maintained when the varnish, oil or compound is in the cup. It is, therefore, necessary to check first the revolutions per minute without the disk suspended in the sample, and again, when running a determination with the disk suspended in the sample. The motor must give the same number of revolutions per minute in each case and this value must be the same as was used for calibrating the suspension.

When the instrument is level adjust the indicator *A* to the zero mark on the dial *D*, when the spindle is suspended in the air, by moving the indicator as necessary. When the indicator has been set it must not be moved again until the test has been completed.

Fill the container *H* with the sample to be tested to a depth of 3.5 cm. A special device *U* is provided to measure this depth. Lay this device across the cup so the pointed end projects into the cup. When the surface of the liquid just touches the point, the depth of the liquid in the cup is 3.5 cm.

Raise or lower the temperature of the oil or varnishes to 21° C. by adding hot or cold water to the water bath, always stirring the sample well until a uniform temperature is secured. This is imperative. The sample may be stirred by rotating the sample cup frequently. It may also be stirred by lifting the spindle from the points *p* and stirring with the disk *G* holding the spindle by the barrel *E* and stirring by giving the disk an up-and-down movement in the sample cup. In the case of compounds, it is necessary to stir in this manner. In testing varnishes and oils, usually sufficient stirring can be obtained by rotating the cup while holding the barrel *E* to keep the disk stationary. If the spindle is removed from the points *p* it must always be suspended again with the same flat side of the supporting triangular button against the supporting arm so that the zero position is not changed.

If, when resuspending the spindle from points *p* it is noted that the zero point has moved, do not reset the indicator *A* as the change probably is due to some torsional effect produced by the sample. This may be especially noticed when testing compounds. Rotate the cup and take the reading without resetting the indicator.

When reading the thermometer have the bulb in the sample midway between the disk and the container wall and not resting on the bottom. Test the temperature at various points in the container to determine if a uniform temperature has been secured.

When a uniform temperature of 21° C. is secured, start the cup rotating by closing the switch *R*. Keep a hand on the switch and watch the scale on the disk *D*. If there is any danger that the deflection will go beyond the maximum limit for the suspension being used, open the switch immediately. Insert the next strongest wire suspension into the spindle and repeat as above indicated. When changing suspensions it is necessary to again set for zero. This may be accomplished without removing the sample, by simply removing the water bath, *I*, with its sample container, *H*, and then suspending the spindle with its new suspension on *p*, and leveling and adjusting as described above. It is necessary, of course, to thoroughly clean the disk, *G*, when doing this for if any varnish film should dry on the disk, the uneven or rough surface thus produced on the disk would cause an erroneous reading. A suspension wire should never be allowed to deflect beyond its maximum limit, for beyond this point a permanent set would be produced in the wire and a new calibration of the wire would have to be made or probably a new wire would have to be used. Table I gives a maximum and minimum limit for suspensions now in use. If the deflection is less than this minimum limit the next weakest suspension must be inserted and the test repeated. The reason for this is that at low deflections a change in slope appears on the calibration curve of the MacMichael degrees *versus* centipoises The percentage error is magnified here and hence a reading that comes up higher in the calibration curve should be used. The maximum limit given may not be the limit to which it is permissible to deflect the wire in order to prevent its acquiring a permanent set. It, however, happens to be the limit of the calibration curve available for that suspension when the wire was calibrated

TABLE I.—MAXIMUM AND MINIMUM LIMITS FOR SUSPENSIONS.

SUSPENSION NUMBER (B & S. Gage No.)	MINIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING	MAXIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING
30 (Weakest)	30	18	125	89
28	20	35	100	200
26	7.5	30	35	175
24	5	70	32.5	400
22	10	200	45	975
21	5	225	40	1800
20	10	750	50	4200
18	4	700	24	4000
16	2	750	11	4000
14 (Strongest)	1	1375	5	5500

Record the deflection in degrees MacMichael and read the viscosity in centipoises from the calibration curve of the suspension used.

NOTE 1.—Before any sets of suspensions are used, they must be calibrated as noted under heading "Calibration of Suspensions."

NOTE 2.—The following table gives the diameter of the wires (new American music wire gage) used in making the suspensions and the maximum limit of torsion

in degrees MacMichael to which they may be subjected before they acquire a permanent set:

SUSPENSION NUMBER (B. & S. Gage No.)	DIAMETER WIRE, IN.	TORSIONAL LIMIT, DEG. MACMICHAEL
30 (Weakest)	0.0100	125
28	0.0126	118
26	0.0159	110
24	0.0201	102
22	0.0254	92
21	0.0285	81
20	0.0320	73
18	0.0403	55
16	0.0508	35
14 (Strongest)	0.0641	5

NOTE 3.—Not all of the suspension noted above are required in testing varnish Suspensions 22, 21 and 20 will be sufficient for practically all varnishes. The heavier wires 18, 16 and 14 are used for very viscous materials.

CALIBRATION OF SUSPENSIONS.

In order to calibrate the torsion wire suspensions used in this apparatus to measure viscosity, a number of samples of oil and a sample of pure castor oil should be prepared and sent to the U. S. Bureau of Standards for determination of absolute viscosity at various temperatures. The following are typical data as supplied by the Bureau of Standards on four standard samples of oil:

OIL SAMPLE	TEMPERATURE, DEG. CENT.	VISCOSITY, CENTIPOISES
No. 1. Mineral Oil (Transformer) 63 seconds Saybolt viscosity at 100° F	10	29.95
	20	18.6
	30	12.44
No. 2. Mineral Oil (Transformer) 104 seconds Saybolt viscosity at 100° F	10	72.50
	20	41.02
	30	25.40
No. 3. Mineral Oil (Lubricating) 297 seconds Saybolt viscosity at 100° F	10	405
	20	169.9
	30	89.64
No. 4. Castor Oil, U. S. P. (AA)	10	2693
	15	1704
	20	1104
	25	746

The viscosity of sample No. 1 is so low that even with the weakest suspension only a very small deflection is secured. As the percentage of error is higher at small deflections than at large deflections, such a sample should not be used. These samples must have their absolute viscosities checked at least once a year as it has been found that the oils undergo some change on standing over long periods.

The calibration of the wires is made by testing the standardized samples of oil, following the directions as given above under heading "Directions for Making Viscosity Measurement on Varnishes." Tests are made at the same temperatures as used by the Bureau of Standards for their absolute viscosity tests. The above standard samples would be used as follows:

	SUSPENSION NUMBER
Sample No. 2 at 10° C.—20° C.—30° C........	30, 28, 26, 24, 22 and 21
" " 3 " 10° C.—20° C.—30° C........	21
" " 3 " 20° C.—30° C................	26, 24, 22 and 21
" " 4 " 10° C........................	18, 16 and 14
" " 4 " 15° C........................	20, 18, 16 and 14
" " 4 " 20° C........................	21, 20, 18 and 16
" " 4 " 25° C........................	21, 20, 18 and 16

The degrees MacMichael obtained for each suspension on each sample at each temperature are plotted against corresponding U. S. Bureau of Standards absolute viscosity figures (centipose) for those samples at the same temperatures and a line is drawn through these points. The line should be straight except possibly at low deflections where the error is correspondingly high.

Once every two months the suspensions should be recalibrated. In this recalibration the viscosities obtained as read from the plotted curve are compared with the Bureau of Standards viscosities and if they agree within 10 per cent, the curve need not be replotted. In cases of low viscosities 15 per cent error is allowable. If the majority check tests show a larger error, a new curve should be plotted for the suspension

APPENDIX II

DIELECTRIC STRENGTH TESTS ON COPPER BASE

Where it is desired to make dielectric strength tests of solid films of varnish (as distinguished from the specimens prescribed in the methods, which are a combination of varnish and paper fibers), it is recommended that copper be used as the base as formerly required in the methods. The following are the directions for preparing and testing such specimens:

1. (*a*) Specimens are prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which is at the consistency prescribed in Section 5 (*b*) of the methods.

(*b*) Each specimen is dipped twice, once in each direction, in order to give a more uniform thickness of coating. The specimen is dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish are dried in free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period six times as long as that determined in accordance with Section 7 of the methods.

(*d*) Specimens of baking varnish are drained and then baked after each dip for a period three times as long as that determined in accordance with Section 7 of the methods.

(*e*) The final thickness of the film of varnish on each side of the specimen is between 0.044 mm. (0.0018 in.) and 0.052 mm. (0.002 in.).

2. (*a*) The dielectric strength of the two films of varnish is determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage shall be increased at a rate of approximately 0.5 kv. per second. The electrodes shall be polished and cleaned after each puncture. As the temperature of the electrodes increases after a number of tests, it is advisable to change the electrodes after every twenty punctures. Ten such punctures are to be made at various points selected at random on each specimen. After testing, the thickness of the specimen shall be determined by making five measurements on a strip cut diagonally across the specimen. The measurements shall be equally spaced along the strip except in the case of a measurement being to close to a point of puncture. The average of the five measurements shall be considered as the thickness of the specimen.

NOTE.—When necessary, in order to get ten punctures, additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 100 volts. The apparatus shall comply with the Standards of the American Institute of Electrical Engineers.

3. The volts at puncture, the net thickness of insulation and the volts per mil of net thickness shall be reported for each of the ten tests together with the average, maximum and minimum volts per mil.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
FRICTION TAPE FOR GENERAL USE FOR ELECTRICAL PURPOSES[1]

A.S.T.M. Designation: D 69 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE, 1920; ADOPTED IN AMENDED FORM, 1924; REVISED, 1928; REISSUED AS TENTATIVE, 1932; REVISED, 1934, 1935.

Scope

1. These specifications cover friction tape commonly used for protecting and binding in place, insulation applied to joints of electrical wires and cables, and for other electrical and mechanical purposes. The tape consists of cotton sheeting that has been impregnated with an adhesive insulating compound and cut into rolls of narrow width.

MANUFACTURE

Cotton Sheeting

2. The cotton sheeting shall be evenly and firmly woven from good cotton and as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice. The threads shall run in as straight lines as possible, without waving, so as to reduce to a minimum the raveling of the cloth when cut into tape.

Frictioning Compound

3. The frictioning compound shall be a tacky adhesive insulating compound containing practically no free sulfur or other substances which would have a deteriorating effect on copper or other metals, or on the fabric.

Impregnation of Fabric

4. The fabric shall be thoroughly impregnated and evenly covered on both sides with the frictioning compound.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

These specifications are in effect a revision of, and replace the former Standard Specifications for Friction Tape for General Use for Electrical Purposes (A.S.T.M. Designation: D 69 - 28), which standard was accordingly discontinued in 1932.

Adhesiveness of Compound

5. The compound shall adhere firmly to the fabric, and shall not pull away from the fabric so as to leave bare spots when adjacent layers of tape are separated.

SAMPLING

Sampling

6. (*a*) The tape offered for inspection shall be divided into one or more lots of approximately equal numbers of rolls in accordance with the following table:

ROLLS OFFERED FOR INSPECTION	NUMBER OF LOTS
Up to 250	1
251 to 750	2
751 to 1500	3
1501 to 3000	4
3001 to 5000	5
Over 5000	5 plus 1 for each additional 1000 rolls.

The lots shall be marked for identification and one sample roll shall be taken at random from each lot for purpose of tests and marked to correspond with the lot from which it was selected. Unless otherwise specified, one specimen from each sample roll shall be tested in accordance with the specifications.

(*b*) At least 2 ft. of the outer layer of each roll selected for purpose of tests shall be removed and discarded before taking test specimens.

(*c*) The tape required for test specimens shall be unwound from the roll at a slow uniform rate without jerking.

CHEMICAL AND PHYSICAL PROPERTIES AND TESTS

Discoloration of Copper

7. The discoloration of copper test shall be made only when requested by the purchaser. Five superimposed layers of tape shall be wound on a clean, bright, smooth copper rod, approximately $\frac{1}{4}$ in. in diameter and 3 in. in length, and baked at 100 C. (212 F.) for 16 hr. in a sealed test tube. At the conclusion of the test the blue-black color, characteristic of copper sulfide, shall not appear on the rod at the edge of the tape.

Pinholes

8. The number of pinholes in a specimen of three consecutive yards of tape selected at random from any portion of the sample

roll shall not exceed six for $\frac{3}{4}$-in., eight for 1-in., twelve for $1\frac{1}{2}$-in., and sixteen for 2-in. tape. Ruptures of the insulating film at the extreme edges of the tape, due to the slight tearing action of the cutting knife, shall not be considered pinholes.

Determination of Pinholes

9. The number of pinholes shall be determined while the tape specimen is held over a slot in the top of an illuminated box. The box shall be approximately 8 in. in width by 8 in. in height and 18 in. in length, inside dimensions. The slot shall be 2 in. in width by 12 in. in length. The box shall be painted white inside and illuminated by a 25-watt lamp. The slot shall be covered with clear glass set flush with the top of the box. Means shall be provided to limit the light to the width of the tape.

Tensile Strength

10. The tensile strength of the tape specimen shall be not less than 40 lb. per inch of width. The initial distance between the jaws of the testing machine shall be 12 in. and the rate of separation of the jaws shall be 20 in. per minute.

Adhesion Test

11. (*a*) *Cold Adhesion Test.*—The adhesion between adjacent layers of the tape shall be determined as follows: A specimen 23 in. in length shall be removed from the sample roll, care being taken not to touch the surface to be tested with the hands or otherwise. One end of the specimen shall be inserted in the slot of the mandrel described below and 2 in. of the tape shall be wound on the mandrel. A weight of 10 lb. per inch of width shall then be attached to the end of the specimen and 19 in. of the tape shall be wound on the mandrel at a uniform rate of 12 in. per minute. The tape shall be allowed to remain 3 min. with the weight attached, after which a weight of 4 lb. per inch of width of tape shall be substituted for the weight of 10 lb. per inch of width, and the tape allowed to unwind. After 2 in. have unwound, the rate of unwinding shall be not greater than 15 in. in 1 min. The temperature of the room and the temperature of the tape shall be not less than 20 C. (68 F.) nor more than 22.2 C. (72 F.), except that tape meeting the adhesion test when tested at a higher room temperature shall not be rejected. The relative humidity at the temperature tested shall not exceed 80 per cent.

The mandrel used shall be $\frac{1}{4}$ in. in diameter with a slot approximately $\frac{1}{16}$ in. in width and long enough to accommodate the full width of tape, and shall be mounted in a level position in ball bearings of the Fafnir Bearing Co., Catalog No. 36, Serial No. 30, extra small, or equivalent ball bearings. The mandrel shall turn freely under a weight of $\frac{1}{4}$ oz., suspended from a cotton thread wound in a single layer on the center of the mandrel. See Fig. 1 for a suggested form of tape tester.

(*b*) *Oven Test.*—After a specimen of tape has been exposed to dry air at a temperature of not less than 99 C. (210.2 F.) nor more than 101 C. (213.8 F.) for 16 hr., and after a rest period at room temperature of not less than 1 nor more than 12 hr., the test specimen shall withstand the test prescribed in Paragraph (*a*), except that the weight applied to unwind the tape shall be 3 lb. per inch of width in place of 4 lb. per inch of width.

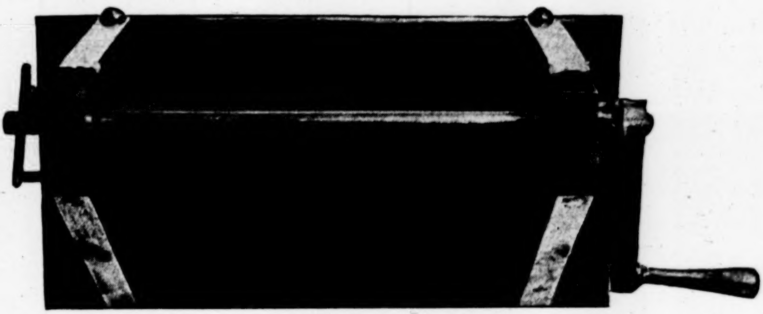

FIG. 1.—Tester for Adhesion Test of Friction Tape.

Tackiness

12. (*a*) The tape shall show tackiness, that is, ability to stick to itself after light contact has been made, in the following combinations: (*1*) front to front, (*2*) back to back, and (*3*) back to front. Two 8-in. specimens shall be cut from each sample roll, care being taken not to touch the surface to be tested with the hands or otherwise. One specimen shall be placed lightly on a clean horizontal surface, then the second placed evenly upon the first. No weight or pressure other than the weight of the specimen shall be applied to the tapes. The two specimens shall be picked up from one end and then stripped slowly from each other starting at the same end. Tackiness in at least two of the combinations (*1*), (*2*) and (*3*) specified shall be such that the point of separation remains approximately in the same horizontal plane as the hands that pull the tape apart. In the back to back combination the specimens shall show some indication of tackiness by the point of separation traveling along the tapes as the hands pull the tape apart.

(*b*) Each combination specified in Paragraph (*a*) shall be tested three times and if more than one test fails to comply with Paragraph (*a*), the tape is non-conforming to the combination in question. Otherwise, it conforms to the combination.

(*c*) New, clean specimens shall be taken for all tackiness tests. The temperature of the room and the temperature of the tape shall be not less than 20 C. (68 F.) nor more than 22.2 C. (72 F.), except that tape meeting the tackiness test when tested at a higher room temperature shall not be rejected. The relative humidity at the test temperature shall not exceed 80 per cent.

Dielectric Strength

13. Each roll selected for purpose of tests shall be tested for dielectric strength. The breakdown voltage shall be not less than 1000 v.

Dielectric Strength Test

14. The dielectric strength shall be determined by placing a specimen approximately 6 in. in length between two flat electrodes $\frac{1}{4}$ in. in width by $4\frac{1}{4}$ in. in length. The edges shall be square and the ends rounded to $\frac{1}{8}$-in. radius cylinders whose axes are parallel to the contact faces of the electrode thus giving an area of contact with the surfaces of the tape of exactly $\frac{1}{4}$ in. in width by 4 in. in length. Under an electrode pressure of 1 lb. per sq. in., a 60-cycle alternating voltage of practically sine wave form shall be applied at a value not exceeding 100 v. and raised at a rate of 100 v. per second until puncture occurs. In order to prevent flashover, increased width may be secured by attaching to each side of the test specimen an added piece of tape, making a $\frac{1}{8}$-in. lap seam carefully rolled down.

Parallelism Test

15. Each sample roll shall be tested for parallelism of the warp threads with the longitudinal axis, as follows: A piece of tape 16 in. in length shall be cut from the sample roll and then torn lengthwise, assisting the tearing by first slitting one end for about $\frac{1}{2}$ in. with a knife. A 2-in. length shall then be cut from each end of one of the torn halves and the ends of the remaining 12-in. length folded together and compared. The difference between the compared widths shall not exceed $\frac{1}{8}$ in.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions

16. (*a*) The tape shall have a nominal thickness of 0.015 in. and shall be made in the following widths: $\frac{3}{4}$ in., 1 in., $1\frac{1}{2}$ in., and 2 in. Each roll shall contain not less than $82\frac{1}{2}$ ft. and not more than 85 ft. of tape.

Permissible Variations

(*b*) The thickness shall not vary from that specified by more than ±0.002 in., nor the width by more than $\pm\frac{1}{32}$ in.

Measurement of Thickness and Width

17. The thickness of the tape shall be determined by means of a micrometer graduated to 0.001 in. and having a presser foot 0.25 in. ± 0.01 in. in diameter, exerting a total force of 9 oz. ± 0.1 oz. The load shall be applied by means of a weight. Five thickness and five width measurements shall be made at random in a length of not less than 3 ft. on each sample roll and the maximum, minimum and average of these five measurements shall be reported.

PACKING AND MARKING

Packing

18. Each roll shall be wrapped in paraffin paper or its equivalent or metal foil and, unless otherwise specified, enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents.

Marking

19. Each box shall be marked with the name of the manufacturer or trade mark, together with the nominal width and length of the tape.

INSPECTION AND REJECTION

Time of Inspection

20. The tape shall be inspected and tested either at the place of manufacture before shipment or at the place of delivery within 4 weeks from date of delivery.

Storage and Guarantees

21. The tape shall be stored in the original boxes and preferably in a cool, dark location. Tape shall not be stored in close proximity to steam pipes, radiators or other sources of heat. The manufacturer shall guarantee to replace tape which at any time within 8 months after acceptance of the tape, if properly stored, will not meet the cold adhesion test specified in Section 11 (*a*), except that a weight of 3 lb. per inch of width of tape shall be substituted for the 4 lb. per inch, during unwinding.

Retests and Rejection

22. (*a*) The purchaser reserves the right to reject any part of the shipment that does not comply with Sections 18 and 19.

(*b*) If the tape fails in any one test of those prescribed in these specifications, two additional rolls shall be selected and subjected to that test. If either of these two additional rolls fails, the lot represented by the test rolls shall be rejected.

(*c*) The manufacturer shall replace the rejected tape and shall pay freight charges for the return of such material.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
RUBBER INSULATING TAPE[1]

A.S.T.M. Designation: D 119 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1921; REVISED, 1922, 1927, 1928, 1932, 1934, 1935.

Scope

1. These specifications cover rubber insulating tape suitable for the insulation of joints in electrical wires and cables and for other insulating purposes.

MANUFACTURE

Compound

2. The tape shall consist of an unvulcanized or partially vulcanized rubber insulating compound. The compound shall be well, evenly and smoothly calendered, cut to the specified widths and tightly wound in rolls with a separator between layers. Preferably, the tape shall be dark gray in color.

Separator

3. The separator shall be parchment paper or glazed sheeting which shall be interposed between adjacent layers and cover the outside of the tape. The outside end of the roll shall be securely fastened. Upon originally unwinding the roll the separator shall show no undue tendency to stick to the rubber or to ravel.

CHEMICAL AND PHYSICAL PROPERTIES

Composition of Rubber Compound

4. The rubber compound shall contain not less than 30 per cent of the best quality crude Hevea rubber, nor more than 0.5 per cent of free sulfur to which may be added small percentages of antioxidant, waxy hydrocarbons and carbon black. The remainder shall consist of suitable inorganic mineral fillers. The compound shall contain no organic matter other than that specified in this section. The percentages shall be based on the weight of the original compound.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

Tensile Strength and Elongation

5. (*a*) The tensile strength of the tape shall be not less than 250 lb. per sq. in.

(*b*) The elongation of a 2-in. gage length determined simultaneously with the tensile strength test shall be not less than 300 per cent.

Dielectric Strength

6. The dielectric strength of the tape shall be not less than 350 v. per mil of thickness.

Fusion and Tackiness

7. The tape shall meet the fusion and tackiness tests specified in Sections 17 and 18.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions

8. The tape shall conform to the following nominal dimensions:

WIDTH, IN.	THICKNESS, IN.	LENGTH, FT.
$\frac{3}{4}$	0.030	30
$\frac{3}{4}$	0.030	15[a]
2	0.030	15

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[a] Unless otherwise specified on the order, $\frac{3}{4}$-in. tape shall be supplied in rolls having a nominal length of 30 ft.

Permissible Variations in Dimensions

9. The thickness shall not vary from the nominal thickness more than ± 0.003 in. and the width not more than $\pm \frac{1}{32}$ in. The length of the tape per roll shall be not less than the nominal length, nor the average length more than 5 per cent in excess of it.

PACKING AND MARKING

Packing

10. Each roll shall be enclosed in a suitable box.

Marking

11. Each box shall be marked with the name of the manufacturer or trade mark and the nominal width and length of the tape.

SAMPLING

Sampling

12. (*a*) All tape offered for inspection shall be divided into one or more lots of approximately equal numbers of rolls in accordance with the following table:

ROLLS OFFERED FOR INSPECTION	NUMBER OF LOTS
Up to 250	1
251 to 750	2
751 to 1500	3
1501 to 3000	4
3001 to 5000	5
Over 5000	5 plus 1 for each additional 1000 rolls

The lots shall be marked for identification and one sample roll shall be taken at random for purpose of tests from each lot and marked to correspond with the lot from which it was selected. Unless otherwise specified, one specimen from each sample roll shall be tested in accordance with the specifications.

(*b*) At least 2 ft. of tape from each roll shall be removed and discarded before taking test specimens.

METHODS OF TEST

Chemical Analysis

13. The chemical analysis of the rubber compound shall be made in accordance with the short procedure described in Sections 1 to 14 of the Standard Methods of Chemical Analysis of Rubber Products (A.S.T.M. Designation: D 297) of the American Society for Testing Materials.[1]

Room Temperature

14. The temperature of the room in which the tensile strength, elongation and fusion tests are made shall be between 68 and 82 F. (20 and 28 C.).

Tensile Strength and Elongation Tests

15. The tests for tensile strength and elongation shall be performed in accordance with the Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 – 35 T) of the American Society for Testing Materials,[2] with the following exceptions:

(*a*) The room temperature shall be as specified in Section 14.

(*b*) The test specimens shall be cut from a laminated sample, two plies thick, carefully rolled together to avoid entrapped air. The thickness of the composite specimen shall be used in calculating the tensile strength.

(*c*) The dumbbell-shaped $\frac{1}{2}$ by 2-in. test specimen shall be used and shall be cut with the A.S.T.M. standard die as shown in Figs. 2 and 3 (Die A) of Tentative Methods D 412, except that the ends of the specimen cut from $\frac{3}{4}$-in. tape need not be full width. In placing the parallel gage marks on the test specimen care shall be taken not to cut the stock.

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1130.

[2] See p. 1159.

(*d*) Three specimens, free from visible defects, from each sample roll shall be tested. The average of the three tests shall be reported.

Dielectric Strength Test

16. The dielectric strength shall be determined by placing a specimen approximately 6 in. in length between two flat electrodes $\frac{1}{4}$ in. in width by $4\frac{1}{4}$ in. in length. The edges shall be square and the ends rounded to $\frac{1}{8}$-in. radius cylinders whose axes are parallel to the contact faces of the electrode thus giving an area of contact with the surfaces of the tape of exactly $\frac{1}{4}$ in. in width by 4 in. in length. Under an electrode pressure of 1 lb. per sq. in., a 60-cycle alternating current voltage of practically sine wave form shall be applied at a value less than 1000 v. and raised at the rate of 1000 v. per sec. until puncture occurs. In order to prevent flashover, increased width may be secured by attaching to each side of the test specimen an added piece of tape, making a $\frac{1}{8}$-in. lap seam carefully rolled down.

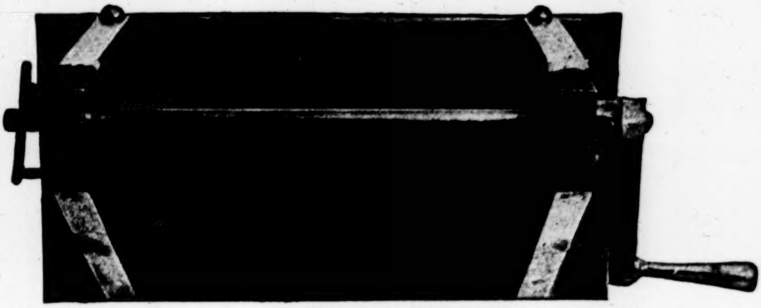

FIG. 1.—Tester for Fusion Test.

Fusion Test

17. (*a*) A specimen 7 in. in length shall be taken from the roll, care being taken not to touch the surface to be tested with the hands or otherwise and 2 in. of the specimen wound on the mandrel, and then a weight of 4 lb. per inch of width of tape shall be attached to the end of the specimen. Should this weight not be sufficient to elongate the tape 200 per cent, additional downward force shall be applied by hand until the desired elongation has been produced. The tape shall then be wound on the mandrel at a uniform rate of 12 in. per min. and allowed to stand for 3 min. with the weight attached. It shall then be allowed to unwind slowly until the fused turns are reached. The mandrel shall revolve not more than two and one-half turns

before the fused turns are reached. The tape shall sustain the weight for 2 min. without further unwinding or shall break at the point of unwinding.

(*b*) The mandrel used shall be $\frac{1}{4}$ in. in diameter and shall be mounted in a level position in ball bearings of the Fafnir Bearing Co. Catalog No. 36, Serial No. 30, extra small or equivalent ball bearings. The mandrel shall turn freely under a weight of $\frac{1}{4}$ oz., suspended from a cotton thread wound in a single layer on the center of the mandrel. See Fig. 1 for a suggested form of tape tester.

Tackiness Test

18. A specimen 7 in. in length shall be taken and wound on the mandrel in the same manner as described in Section 17. Instead of leaving the weight suspended for 3 min. it shall be immediately removed. The tape shall show no tendency to unwind from the mandrel.

Measurement of Thickness and Width

19. The thickness of the tape shall be determined by means of a micrometer graduated to 0.001 in. and having a presser foot 0.25 in. ± 0.01 in. in diameter, exerting a total force of 9 oz. ± 0.1 oz. The load shall be applied by means of a weight. Five thickness and five width measurements shall be made at random in a length of not less than 3 ft. on each sample roll and the maximum, minimum and average of these five measurements shall be reported.

INSPECTION AND REJECTION

Inspection

20. The tape shall be tested and inspected either at the place of manufacture before shipment or at the place of delivery within 4 weeks from date of delivery.

Storage and Guarantees

21. The tape shall be stored in the original boxes and preferably in a cool, dark location. Tape shall not be stored in close proximity to steam pipes, radiators or other sources of heat. Provided the tape has been properly stored, the manufacturer shall guarantee to replace, without charge, any tape which at any time within 8 months after receipt of a shipment will not meet the fusion test specified in Section 17 or to which the separator becomes unduly attached.

Retests and Rejections

22. (*a*) The purchaser reserves the right to reject any part of the shipment that does not comply with Sections 10 and 11.

(*b*) If the tape fails in any one test of those prescribed in these specifications, two additional rolls shall be selected and subjected to that test. If either of these two additional rolls fails, the lot represented by the test rolls shall be rejected.

(*c*) The manufacturer shall replace the rejected tape and shall pay freight charges for the return of such material.

TENTATIVE SPECIFICATIONS
FOR
INSULATED WIRE AND CABLE: CLASS AO, 30 PER CENT HEVEA RUBBER COMPOUND[1]

A.S.T.M. Designation: D 27 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1916; REVISED, 1921, 1928, 1931, 1933, 1934, 1935.[2]

Scope

1. These specifications cover the conductors, insulation, cable tape, cotton braid and lead sheaths of Class AO rubber insulated wire and cable. The design and factor of safety depend upon the service conditions and shall be at the option of the purchaser.

(*A*) CONDUCTOR

MANUFACTURE

Material

2. The conductor shall be of soft annealed copper, properly tinned, and have the properties and characteristics herein required.

Strand

3. Each individual wire of a stranded conductor shall be considered separately and shall be designated as a strand.

Shape

4. Each solid conductor and each strand shall be round and reasonably free from imperfections.

Stranding

5. The stranding shall conform to the requirements of Table I and shall be either standard concentric or flexible as specified in the order.

Density

6. For the purpose of calculating weights, cross-sections, etc., in conductivity determinations, the density of copper shall be taken as 8.89 g. per cu. cm. (See Appendix.)

PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter and Area

7. (*a*) *Permissible Variation.*—When the diameter of solid conductors and strands is specified, the permissible variation from the

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Latest revision accepted by Committee E-10 on Standards, September 28, 1935.

specified value shall not exceed 1 per cent under or 2 per cent over for wire 0.02 in. in diameter and larger, and 0.1 mil under for wire less than 0.02 in. in diameter.

NOTE.—These limits differ from those in the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (A.S.T.M. Designation: B 33) of the American Society for Testing Materials[1] because of the additional manipulation to which the wire is subjected subsequent to the stage where Specifications B 33 apply.

When the area of cross-section of cables is specified, the permissible variation shall not exceed 1 per cent under the specified value.

(*b*) *Method of Gaging Diameter.*—When wire is submitted in coils, each coil shall be gaged in three places, one near each end and one approximately at the middle. When wire is submitted on spools or reels, approximately 12 ft. of the wire shall be reeled off and the wire then gaged in six places between the second foot and the twelfth foot from the end.

TABLE I.—STRANDING OF INSULATED CONDUCTORS.

(*1*) For intermediate sizes use stranding for next larger size.
(*2*) In assembly column, "37 by 19 rope lay," signifies 37 strands of 19 wires assembled like a rope.
(*3*) Flexible stranded Nos. 16 and 18 A. w. g. shall consist of No. 30 A. w. g. wires bunched and bound with a soft cotton wind or other material
(*4*) Conductors of No. 0000 and smaller are often made solid and this table of stranding should not be interpreted as excluding such practice.

Size of Conductors	Standard Concentric Stranding,[a] Number of Wires	Flexible Stranding	
		Number of Wires	Assembly
2 000 000 cir. mils	127	703	37 by 19 rope lay
1 500 000 cir. mils	91	703	37 by 19 rope lay
1 000 000 cir. mils	61	427	61 by 7 rope lay
500 000 cir. mils	37	427	61 by 7 rope lay
300 000 cir. mils	37	259	37 by 7 rope lay
0 000 A. w. g	19	133	19 by 7 rope lay
1 A. w. g	19	133	19 by 7 rope lay
2 A. w. g	7	133	19 by 7 rope lay
4 A. w. g	7	49	7 by 7 rope lay
8 A. w. g	7	49	7 by 7 rope lay
10 A. w. g	7	37	Concentric
16 A. w. g	7	26	Bunched
18 A. w. g	7	16	Bunched

[a] The standard concentric stranding in this table agrees with Table XII of *Circular No. 31*, "Copper Wire and Cables," U. S. Bureau of Standards; and also Table II of Standard No. 30 "Wires and Cables" of the American Institute of Electrical Engineers.

(*c*) *Calculation of Area.*—The area of cross-section of wire shall be calculated from the average of the measurements of the diameter made in accordance with Paragraph (*b*). The area of cross-section of cable shall be considered to be the sum of the cross-sectional areas of its component wires, when laid out straight and measured perpendicular to their axes.

(*d*) *Rejection.*—A coil or reel shall be rejected if the average diameter obtained from the measurements made in accordance with Paragraph (*b*), or the area calculated in accordance with Paragraph (*c*), is not within the limits specified in Paragraph (*a*).

A coil or reel shall be rejected if any individual measurement of diameter or of area of cross-section is not within twice the limits of Paragraph (*a*).

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 777.

PHYSICAL PROPERTIES AND TESTS

Tensile Properties

8. (*a*) Each solid conductor and each strand previous to stranding shall be so drawn and annealed that after tinning it shall conform to the values in Table II.

After stranding, the tensile strength of each strand shall not exceed that specified in Table II by more than 5 per cent and the minimum elongation in 10 in. shall not be less than that specified in Table II by more than 5 per cent.

(*b*) For nominal diameters between listed sizes the requirements shall be those of the next larger sizes indicated in Table II.

Tension Tests

9. (*a*) *Method of Test.*—Tension tests shall be made on fair samples and the elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks originally 10 in. apart. The specimen shall break between the bench marks and not closer than 1 in. to either mark.

TABLE II.—TENSILE REQUIREMENTS OF CONDUCTORS.

Size of Conductor		Maximum Tensile Strength, lb. per sq. in.	Minimum Elongation in 10 In., per cent
Diameter, in	A.w.g. Number		
0.460 to 0.290	0000 to 1	36 000	30
0.289 to 0.103	2 to 10	37 000	25
0.102 to 0.021	12 to 24	38 500	20
0.020 to 0.012	25 to 28	39 000	15
0.011 to 0.003	29 to 40	40 000	10

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 25.

(*c*) *Retests and Rejections.*—If upon testing a sample from a coil, reel or spool of wire, the results are found to be above the stated value for tensile strength or below the stated value for elongation, tests upon two additional samples will be made and the average of the three tests shall determine acceptance or rejection.

Conductivity

10. The conductivity of the conductors after tinning shall be not less than that specified in Table III.

TABLE III.—CONDUCTIVITY REQUIREMENTS.

DIAMETER, IN.	A.W.G. NUMBER	CONDUCTIVITY, PER CENT
0.460 to 0.290	0000 to 1	97.65
0.289 to 0.103	2 to 10	97.15
0.102 to 0.021	12 to 24	96.15
0.020 to 0.012	25 to 28	94.15
0.011 to 0.003	29 to 40	93.15

NOTE.—The above values for conductivity conform to the International Annealed Copper Standard. (See Appendix I.)

Tinning Test

11. (*a*) The continuity of the tin coating of each sample before stranding or insulating shall be determined by the sodium polysulfide test which shall be made in accordance with the requirements of Sections 4 to 10, inclusive, of the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (A.S.T.M. Designation: B 33) of the American Society for Testing Materials.[1]

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 25.

(*c*) *Retests and Rejections.*—If the specimens tested in accordance with Paragraph (*a*) shows any signs of blackening, two more specimens shall be tested. If one of these two additional specimens shows any blackening, that coil or reel shall be rejected. If both specimens are free from any signs of blackening, the coil or reel shall be accepted. If more than 10 per cent of the samples in the entire order fail, all of the wire shall be rejected. If 10 per cent or less of the samples in the entire lot fail, each coil, reel or length may be tested and accepted or rejected upon the results of the individual tests.

(*B*) INSULATION

Workmanship

12. (*a*) Wires and cables ordered under these specifications shall be insulated with Class AO rubber compound. Where Class A rubber compound is desired, the order shall be placed under the Tentative Specifications for Insulated Wire and Cable: Class A, 30 per cent Hevea Rubber Compound (A.S.T.M. Designation: D 393 - 34 T),[2] and where performance rubber compound is desired, under the Tentative Specifications for Insulated Wire and Cable: Performance Rubber Compound (A.S.T.M. Designation: D 353 - 35 T)[3] of the American Society for Testing Materials.

(*b*) The insulation shall consist of a properly vulcanized rubber compound which shall be homogeneous in character, tough, elastic and applied concentrically about the conductor and shall fit tightly thereto. Where the insulation is applied in more than one layer, adjacent layers shall be vulcanized into a homogeneous mass.

(*c*) *Shielding.*—Braided cables on ungrounded neutral circuits of 3501 v. and over shall have shielding over the insulation.

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 777.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34 Part I, p. 1126 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1173.

[3] See p. 1141.

The shielding shall consist of a thin tinned copper tape or a braid of fine tinned copper wires.

(*d*) The insulation of braided wires up to No. 7 A.w.g., inclusive, shall be covered with a single cotton braid. In multiple conductor cables the individual conductors shall not be braid-covered unless so specified. On larger sizes the fibrous covering shall consist of a cable tape and a cotton braid or two cotton braids. The cable tape shall conform to the requirements specified in Sections 53 to 56, inclusive. The cotton braid shall be applied in accordance with Sections 57 to 61, inclusive, and shall be finished in accordance with Sections 62 to 67.

(*e*) Where repairs or joints are made in the insulation, the work shall be done in such manner that the repaired part of the joint, and all parts affected in the process, shall be as strong and durable electrically and mechanically as the remainder of the insulation and shall not exceed the limitations on the thickness specified in Section 17.

MANUFACTURE

Composition

13. (*a*) Class AO rubber compound shall contain exclusively not less than 30 per cent nor more than 33 per cent of the best quality Hevea rubber which has not previously been used in a rubber compound, solid waxy hydrocarbons, suitable mineral matter, antioxidants, organic accelerators, and sufficient sulfur to properly vulcanize the compound.

(*b*) The mineral matter shall be dry.

(*c*) The waxy hydrocarbons used shall be solid at 54° C. and shall be free from saponifiable matter.

(*d*) Contamination of the compound, such as by the use of impregnated tapes, will not excuse the manufacturer from conforming to these specifications.

CHEMICAL PROPERTIES

Quantitative Requirements

14. The insulation after vulcanization shall conform on analysis to the following requirements expressed as percentages by weight of the whole sample:

	MAXIMUM	MINIMUM
Rubber, per cent	33	30
Waxy hydrocarbons, per cent	4	..
Free sulfur, per cent	0.7	..

	30 PER CENT RUBBER[a]	33 PER CENT RUBBER[a]
Saponifiable acetone extract, max., per cent	2.00	2.20
Unsaponifiable resins, max., per cent	1.00	1.10
Chloroform extract, max., per cent	0.90	1.00
Alcoholic potash extract, max., per cent	0.55	0.60
Total sulfur, max., per cent	2.10	2.30

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[a] For percentages between 30 and 33, the limits shall be in proportion to the percentage of rubber found.

Qualitative Requirements

15. (*a*) The acetone solution shall not fluoresce.

(*b*) The hydrocarbons shall be solid, waxy and not darker than a light brown.

(*c*) The chloroform extract (60 ml.) shall not be darker than a straw color.

PHYSICAL PROPERTIES

Physical Properties

16. The insulation shall conform to the following requirements as to physical properties:

Tensile strength, min., lb. per sq. in.		1200
Tensile stress at 200 per cent elongation, min., lb. per sq. in.		300
Elongation at rupture, min., per cent		400
Set in 2-in. gage length, max., in.		$\frac{3}{8}$
Depreciation in tensile strength and elongation after oxygen bomb test, max., per cent		25
Depreciation in tensile strength and elongation after Geer oven test, max., per cent		15
Specific gravity, min.	30 per cent rubber	1.75[a]
	33 per cent rubber	1.67[a]

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[a] For percentages between 30 and 33, the specific gravity limits shall be in proportion to the percentage of rubber found.

THICKNESS

Thickness

17. (*a*) The average thickness of the insulation shall be not less than 95 per cent of the thickness specified in Table IV for insulations less than $\frac{4}{64}$ in. thick and not less than 90 per cent of the specified thickness for insulations of $\frac{4}{64}$ in. and over.

(*b*) The thicknesses in Table IV apply to single conductor cable and the individual conductors of multiple conductor cables, leaded or braided, except special applications such as aerial, non-leaded submarine, and vertical riser cable.

NOTE.—In Appendix II will be found an interpretation of the insulation thicknesses given in Table IV.

ELECTRICAL PROPERTIES

High Voltage Test

18. Each coil, reel, or length of wire or cable, after vulcanization shall successfully withstand the application of an alternating voltage of not less than that prescribed in Table IV for a period of 5 minutes. (See Sections 47 and 48.)

TABLE IV.—THICKNESS OF INSULATION AND ALTERNATING TEST VOLTAGE.

NOTE 1.—Rated circuit voltage of alternating-current circuits is the phase-to-phase voltage.

NOTE 2.—For an intermediate size of wire or an intermediate rated circuit voltage, the thickness and test voltage shall be that for the next larger size or higher rated circuit voltage.

NOTE 3.—For non-leaded submarine cables, $\frac{1}{32}$ in. should be added to the specified respective walls of insulation in this table for all sizes and voltages.

NOTE 4.—This table applies to wire for use on grounded and ungrounded circuits.

Rated Circuit Voltage	Size of Conductor, A. w. g. Numbers or Circular Mils	Insulation Thickness on each Conductor, sixty-fourths of an inch	Test Voltage
0 to 300	No. 18 to No. 16	2	1 000
0 to 600	No. 14 to No. 9	3	3 000
	No. 8 to No. 2	4	3 500
	No. 1 to No. 0000	5	4 000
	225 000 to 500 000 cir. mils	6	5 000
	525 000 to 1 000 000 cir. mils	7	6 000
	Over 1 000 000 cir. mils	8	7 000
601 to 1000	No. 14 to No. 8	4	5 000
	No. 7 to No. 2	5	6 000
	No. 1 to No. 0000	6	7 500
	225 000 to 500 000 cir. mils	7	9 000
	525 000 to 1 000 000 cir. mils	8	10 000
	Over 1 000 000 cir. mils	9	11 000
1001 to 2000	No. 14 to No. 8	5	6 000
	No. 7 to No. 2	6	7 500
	No. 1 to No. 0000	7	9 000
	225 000 to 500 000 cir. mils	8	10 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	9	11 000
2001 to 3000	No. 14 to No. 8	7	9 000
	No. 7 to No. 2	8	10 000
	No. 1 to No. 0000	8	10 000
	225 000 to 500 000 cir. mils	9	11 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	10	12 500
3001 to 4000	No. 14 to No. 8	9	11 000
	No. 7 to No. 2	9	11 000
	No. 1 to No. 0000	9	11 000
	225 000 to 500 000 cir. mils	10	12 500
	525 000 to 1 000 000 cir. mils	10	12 500
	Over 1 000 000 cir. mils	11	13 500
4001 to 5000	No. 14 to No. 8	10	12 500
	No. 7 to No. 2	10	12 500
	No. 1 to No. 0000	10	12 500
	225 000 to 500 000 cir. mils	11	13 500
	525 000 to 1 000 000 cir. mils	11	13 500
	Over 1 000 000 cir. mils	12	15 000

Insulation Resistance

19. Each coil, reel, or length of wire or cable after being subjected to the high voltage test specified in Section 18 shall have an insulation resistance not less than that given in Table V.

Moisture Absorption

20. (*a*) The increase in the specific inductive capacity of the insulation shall be used as an indication of the amount of moisture asborbed.

(*b*) The specific inductive capacity after 24-hr. immersion in water shall not exceed six. The increase between the ends of the first and the fourteenth days shall not exceed 20 per cent and that between the ends of the seventh and fourteenth days, 5 per cent.

(*c*) The specific inductive capacity shall be determined at either 1000 or 60 cycles. Where measured at 1000 cycles, the voltage impressed upon the conductor shall not exceed 10 volts. Where measured at 60 cycles, the voltage impressed upon the conductor shall be equivalent to a stress of between 30 to 40 volts per mil of insulation.

(*d*) The measurements shall be made as described in Section 52.

TABLE V.—INSULATION RESISTANCE, MEGOHMS-1000 FT. AT 60° F. (15.5° C.).

NOTE 1.—This table is based on a constant, $K = 21\,120$ in the following formula:

$R = K \log_{10} \frac{D}{d}$; where R = resistance in megohms-1000 ft., K = constant.

D = diameter over insulation, on each conductor, and d = diameter over conductor.

NOTE 2.—For an intermediate size, the insulation resistance shall be that of the next larger size.

Size of Conductor, A. w. g. Numbers or Circular Mils	Solid or Stranded	Diameter in Inches	Insulation Thickness in Sixty-fourths of an Inch									
			2	3	4	5	6	7	8	9	10	12
No. 18	Solid	0.040	8600	11 100	....	....	....	....	....	....	....	....
No. 16	Solid	0.051	7300	9 500	....	....	....	....	....	....	....	....
No. 14	Solid	0.064	....	8 300	9900	11 300	12 550	13 650	14 600	15 450	16 250	17 650
No. 12	Solid	0.081	....	7 050	8550	9 850	11 000	12 000	12 900	13 750	14 500	15 850
No. 10	Solid	0.102	....	6 000	7350	8 500	9 600	10 500	11 350	12 100	12 850	14 150
No. 8	Solid	0.128	....	....	6200	7 300	8 300	9 150	9 950	10 650	11 350	12 550
No. 6	Stranded	0.184	....	....	4750	5 600	6 400	7 200	7 900	8 500	9 100	10 200
No. 4	Stranded	0.232	....	....	3900	4 700	5 450	6 100	6 700	7 250	7 800	8 850
No. 2	Stranded	0.292	....	....	3250	3 900	4 550	5 150	5 650	6 150	6 650	7 600
No. 1	Stranded	0.332	....	....	....	3 550	4 100	4 650	5 150	5 600	6 100	6 950
No. 0	Stranded	0.373	....	....	....	3 200	3 750	4 200	4 700	5 150	5 550	6 350
No. 00	Stranded	0.418	....	....	....	2 900	3 400	3 850	4 300	4 700	5 100	5 850
No. 000	Stranded	0.470	....	....	....	2 600	3 100	3 500	3 900	4 250	4 650	5 400
No. 0000	Stranded	0.528	....	....	....	2 400	2 800	3 150	3 550	3 900	4 200	4 900
250 000 cir. mils	Stranded	0.575	....	....	....	....	2 600	2 950	3 300	3 650	4 000	4 600
350 000 cir. mils	Stranded	0.681	....	....	....	....	2 250	2 550	2 850	3 150	3 450	4 000
500 000 cir. mils	Stranded	0.814	....	....	....	....	1 900	2 200	2 450	2 700	2 950	3 450
750 000 cir. mils	Stranded	0.998	....	....	....	....	....	1 800	2 050	2 250	2 500	2 900
1 000 000 cir. mils	Stranded	1.152	....	....	....	....	....	1 600	1 800	2 000	2 200	2 600
1 250 000 cir. mils	Stranded	1.289	....	....	....	....	....	....	1 600	1 800	2 000	2 350
1 500 000 cir. mils	Stranded	1.412	....	....	....	....	....	....	1 500	1 650	1 850	2 150
1 750 000 cir. mils	Stranded	1.526	....	....	....	....	....	....	1 400	1 550	1 700	2 000
2 000 000 cir. mils	Stranded	1.631	....	....	....	....	....	....	1 300	1 500	1 600	1 900

METHODS OF TESTING

CHEMICAL ANALYSIS

Sampling

21. Samples of the vulcanized rubber compound for chemical analysis shall be taken after the successful completion of the physical and electrical tests, and before applying impregnating compounds which may contaminate the rubber. The samples shall be taken at the option of the purchaser. The purchaser shall assure himself that all samples are free from contamination and change due to torch heating. Wherever practicable, samples shall be taken at a distance of at least 3 ft. from the end of the wire.

Procedure

22. The insulation shall be analyzed in accordance with (*B*) Complete Procedure as described in the Standard Methods of Chemical Analysis of Rubber Products (A.S.T.M. Designation: D 297) of the American Society for Testing Materials.[1]

Rejection and Retests

23. The purchaser may make a chemical analysis on any one of the samples selected as described in Section 21 to determine if the compound conforms to the requirements of Sections 14 and 15. Failure of any sample selected to conform to the requirements shall be sufficient cause for rejecting the wire which that sample represents, except in the case of failure to conform to the requirements for either or both free sulfur and chloroform extract. In case of such failure, the coil from which the sample was taken shall be rejected and two additional samples shall be selected from the remainder of the order. The remainder of the order shall be accepted if both samples so selected conform to the requirements for free sulfur or chloroform extract. The entire order shall be rejected if either sample fails.

SPECIFIC GRAVITY

Specific Gravity

24. The specific gravity shall be determined in accordance with Section 27 of the Standard Methods of Chemical Analysis of Rubber Products (A.S.T.M. Designation: D 297) of the American Society for Testing Materials.[1]

TENSILE STRENGTH, SET AND ELONGATION AT RUPTURE

Sampling for Physical Tests

25. (*a*) Wire up to and including 250,000 cir. mils in size shall be sampled in accordance with the following requirements:

QUANTITY OF WIRE	NUMBER OF SAMPLES
2000 ft. and under	none
2001 to 10,000 ft.	1 for each 2000 ft. or fraction thereof
10,001 to 100,000 ft.	5 plus 1 for each 10,000 ft. additional over 10,000 ft.
100,001 to 500,000 ft.	14 plus 1 for each 25,000 ft. over 100,000 ft.

(*b*) For wire larger than 250,000 cir. mils, one sample shall be selected from quantities between 1000 and 2000 ft. and for larger quantities double those specified in Paragraph (*a*).

Test Specimen

26. (*a*) *Size.*—The test specimen may be the entire section of the insulation in the case of small wires, or, in the case of a large wire or

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[1] 1933 Book of A.S.T.M. Standards, Part II, p. 1130.

cable, either a segment of a section cut with a sharp knife held tangentially to the conductor or a shaped specimen cut out with a standard die. The test specimen shall be as free as possible from surface incisions and imperfections. There shall be no limit to the cross-section of the test specimen, except as restricted by the capacity of the testing machine.

NOTE.—The removal of the rubber insulation can be greatly accelerated and in most cases a test specimen which is an entire section can be obtained free from surface incisions and imperfections by means of metallic mercury. The mercury should be introduced at one end of the sample between the insulation and the tinned surface of the conductor, and the sample inclined on a support with the end to which the mercury is applied at the top. The separation of the rubber insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury.

(*b*) *Condition and Age.*—Specimens shall not be heated, immersed in water or subjected to any mechanical or chemical treatment not specifically prescribed in these specifications. Specimens for accelerated aging tests shall be taken from the completed wire after the application of the specified covering and shall be aged with all such covering removed. No tests shall be made within 24 hours nor later than 60 days after vulcanization unless agreed to by the manufacturer.

(*c*) *Buffing.*—In the event of any irregularities on the surface of the test specimen, it shall be made smooth and of uniform thickness within 5 per cent of the original thickness by buffing, except when large strands are used, in which case the rubber sample shall be buffed sufficiently to remove all corrugations.

Calculation of Area

27. Calculation of the area of the test specimens shall be made as follows:

(*a*) Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the minimum average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be calculated from its maximum diameter.

(*b*) Where a slice cut from the insulation by a knife held tangent to the wire is used, and the slice so cut has the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. (The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.)

(*c*) Where the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

(*d*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thin, the area shall be calculated as the thickness times the width. (This applies either to a straight test piece or one stamped out with a die, and assumes that corrugations have been removed by buffing.)

(*e*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thick, the area shall be calculated as the proportional part of the area of the total cross-section.

Temperature at Test

28. Physical tests shall be made at a room temperature not less than 65° F. (18.3° C.) nor more than 90° F. (32.2° C.) and the test specimen shall have been kept at the room temperature not less than 30 minutes prior to the test.

Tension Testing Machine

29. The tension testing machine shall be power-driven and preferably of the pendulum type. The machine shall be accurate within 1 per cent of the breaking load. A spring balance type of apparatus may be used if provided with a device which will indicate the actual maximum load at which rupture takes place and if provision is made to prevent recoil of the spring.

Tensile Strength Test Procedure

30. The tensile strength test shall be made on a specimen which has not been previously stretched. The specimen shall have a length of not less than 6 in., and shall be marked with gage marks 2 in. apart and placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. The specimen shall be stretched at the rate of 20 in. per minute (jaw speed) until it breaks. The test specimen shall break between the gage marks. The tensile strength shall be calculated upon the area of the original specimen.

Tensile Stress Test

31. The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the 2-in. gage length marks are 6 in. apart, that is, at 200 per cent elongation. The tensile stress shall be calculated upon the original area of the specimen.

Elongation at Rupture Test Procedure

32. The percentage of elongation at rupture shall be determined simultaneously with the tensile strength and on the same specimen.

The elongation at rupture shall be taken as the distance between gage marks at rupture less 2 in. (the original gage length of the set test specimen). The percentage of elongation at rupture is the elongation in inches divided by the original gage length (2 in.) and multiplied by 100 to express as a percentage.

Set Test Procedure

33. The set test shall be made on a separate test specimen having a length of not less than 6 in. and marked with gage marks 2 in. apart. The specimen shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. and shall be stretched at the rate of 20 in. per minute (jaw speed) until the gage marks are 6 in. apart. The test specimen shall then be released within 5 seconds and the distance between gage marks shall be determined 1 minute after the beginning of release. The set is the difference between this length and the original 2-in. gage length.

Retests, Physical Properties

34. Where tested in accordance with Sections 30, 31, 32 and 33, if a specimen fails to conform to any one of the requirements for tensile strength, tensile stress, set, or elongation at rupture specified in Section 16, two additional specimens shall be taken from the same sample and tested, and the average of the results shall determine whether the material conforms to the requirements.

AGING TESTS

Sampling for Aging Tests

35. For aging tests the wire shall be sampled as follows:

No samples shall be selected where the quantity is less than 2000 ft. of wire or cable.

For sizes less than 250,000 cir. mils, one sample shall be selected for each quantity ordered between 2000 ft. and 50,000 ft. of wire or cable and one additional sample for each additional 50,000 ft. thereafter.

For sizes 250,000 cir. mils and over, one sample shall be selected for each quantity ordered between 2000 ft. and 25,000 ft. of wire or cable and one additional sample for each additional 25,000 ft. thereafter.

Test Specimens

36. Nine test specimens of similar size and shape shall be prepared from each sample selected in accordance with Section 35, three for the determination of the initial or unaged properties, three for the oxygen bomb test and three for the Geer oven test. One specimen of

each three shall be tested and the other two held as spares except that where only one sample is selected all three specimens shall be tested and the average of the results reported.

Aging Test Conditions

37. (*a*) In the case of wire and cable smaller than No. 6 A.w.g. with an insulation thickness less than $\frac{3}{32}$ in., the insulation shall be heated in the oxygen bomb and in the Geer oven without removing the conductor.

(*b*) In the case of wire and cable of No. 6 A.w.g. and larger or with an insulation thickness greater than $\frac{3}{32}$ in., samples approximately square in section shall be cut from the insulation with a cross-section not greater than 0.025 sq. in.

(*c*) Die-cut samples shall be buffed before being subjected to the accelerated aging test wherever the thickness of the sample is $\frac{3}{32}$ in. or greater after buffing.

(*d*) The test specimens shall have no protective covering and shall be suspended vertically in such a manner that they will not come in contact with each other or with the sides of the bomb or oven.

(*e*) Physical tests on both aged and unaged specimens shall be made at the same time. The aged specimens shall have a rest period of not less than 16 hr. nor more than 48 hr. between the completion of the aging and the determination of the physical properties.

Oxygen Bomb Test

38. The test specimens shall be heated in an atmosphere of oxygen at a pressure of 300 lb. per sq. in. at a temperature of from 157 to 159° F. for a period of 96 hours. The weight of the rubber in the bomb shall not be over 2 g. per cu. in. of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least two minutes, when specimens are removed. The bomb temperature shall be recorded automatically on a chart.

Geer Oven Test

39. The test specimens shall be heated at a temperature of from 157 to 159° F. for a period of 96 hours in an oven having a free circulation of fresh air. The oven temperature shall be recorded automatically on a chart.

Retests, Aging

40. Should the first set of specimens selected under Section 35 fail to meet the specifications, two other sets of specimens shall be tested and if either of these sets fails, the coils, reels or lengths will be rejected.

Rejection

41. When ten or more samples are selected in any inspection lot, all coils, reels or lengths may be rejected if more than 10 per cent of the samples fail. If 10 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the results of such individual tests. Where the number of samples selected in any inspection lot is less than ten, all coils, reels or lengths shall be rejected if more than 20 per cent of the samples fail. If 20 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the result of such individual tests.

THICKNESS

Apparatus

42. The thickness measurements may be made with any type of micrometer reading to 0.001 in., suitable for measurements of this character.

Number of Measurements

43. Where the lot of wire to be inspected consists of two coils or reels or less, at least one determination of the thickness shall be made on each coil or reel. Where the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, not less than 10 per cent of the coils or reels shall be selected at random and at least one determination of the thickness made on each coil or reel so selected.

Procedure

44. The average thickness of the insulation shall be taken as one-half the difference between the mean of the maximum and minimum diameters measured at any one point and the average diameter of the conductor measured at the same point. The minimum thickness shall be taken as the difference between a measurement made over the conductor plus the thinnest wall and the diameter of the conductor. (The first measurement is made by "slicing off" the heavier side of the insulation.)

In the case of multiple-conductor cable, the measurements shall be made on the individual wires before being cabled.

Rejection

45. If the thickness of the insulation of any coil or reel is found to be less than the specified value, that coil or reel shall be rejected and a thickness measurement on each of the remaining coils or reels shall be made.

ELECTRICAL TESTS

Place of Testing

46. Electrical tests of wire and cable shall be made at the place of manufacture.

High Voltage Test

47. The high voltage test shall be made with alternating potential from a transformer and generator of ample capacity and in no case less than 5 kva. The frequency of the test voltage shall be not greater than 100 cycles and shall have a wave shape approximating as closely as possible a sine curve.

TABLE VI.—TEMPERATURE COEFFICIENTS.

Temperature		Temperature Coefficient	Temperature		Temperature Coefficient
Deg. Fahrenheit	Deg. Centigrade		Deg. Fahrenheit	Deg. Centigrade	
46	7.8	0.69	61	16.1	1.03
47	8.3	0.71	62	16.7	1.05
48	8.9	0.73	63	17.2	1.08
49	9.4	0.75	64	17.8	1.11
50	10.0	0.77	65	18.3	1.14
51	10.6	0.79	66	18.9	1.17
52	11.1	0.81	67	19.4	1.20
53	11.7	0.83	68	20.0	1.23
54	12.2	0.85	69	20.6	1.26
55	12.8	0.88	70	21.1	1.30
56	13.3	0.90	71	21.7	1.33
57	13.9	0.92	72	22.2	1.37
58	14.4	0.94	73	22.8	1.40
59	15.0	0.97	74	23.3	1.44
60	15.6	1.00	75	23.9	1.48

Rate of Application

48. The initially-applied voltage shall be not greater than the rated voltage and the rate of increase shall be approximately uniform and not over 100 per cent in 10 seconds nor less than 100 per cent in 60 seconds.

High Voltage Testing

49. (*a*) *General.*—Where insulated conductors are subjected to a high voltage test in water they shall be immersed in a grounded water bath and tested while still immersed.

(*b*) *Single Conductor.*—Single conductors shall be tested after 12-hr. immersion and without covering except a tape or braid applied before vulcanization.

Rubber sheathed conductors shall be immersed and tested after the sheath is applied.

Where a metallic sheath is applied, the conductors shall be retested against the sheath.

(*c*) *Multiple Conductor.*—The individual conductors of multiple conductor cables shall be tested before assembling as prescribed in Paragraph (*b*).

After assembly each conductor shall be tested against the adjacent conductors. Where a metallic sheath is applied each conductor shall in addition be tested against the sheath.

Cables having a rubber or other non-metallic waterproof sheath shall be immersed for 12 hr. and the conductors tested against ground. Cables covered with cable tape and braid or double braid with a weather-resistant finish shall not be immersed for testing.

Application of Voltage

50. (*a*) *Single-Conductor Cables.*—Single-conductor cables shall be tested between conductor and sheath or water in which they are immersed.

(*b*) *Multiple-Conductor Cables.*—If a multiple-conductor cable is rated at the same operating voltage between conductor and sheath or water as between conductors, each conductor shall be tested against the other conductors in the cable and against the sheath or water, at the test voltage prescribed for that rated voltage. If a cable is rated at a voltage between conductors and ground different from that between conductors, the test between conductors shall be made at the test voltage prescribed for the rated voltage between conductors and the test between each conductor and sheath or water, shall be made at the test voltage prescribed for the rated voltage between conductors and sheath or water.

The several tests may be made by any arrangement of testing transformers suitable for the prescribed tests, such as one or more transformers supplied from a single-phase source or three transformers connected in star and supplied from a three-phase source.

Insulation Resistance

51. (*a*) The insulation resistance shall be measured after the high-voltage test has been made and while the wire or cable is still immersed in water. The measurement shall be made after one-minute electrification with a continuous e.m.f. of from 100 to 500 volts, the conductor being maintained negative to the water. The temperature of the water shall be within the limits given in Table VI.

Temperature Coefficient

(*b*) If the temperature at which the insulation resistance was measured differs from 60° F. (15.5° C.), the resistance shall be reduced to that at 60° F. (15.5° C.) by multiplying the measured value by the coefficient in Table VI corresponding to the temperature at which the measurement was made.

Moisture Absorption Test

52. (*a*) A 15-ft. sample with all the coverings removed shall be selected at random from the wire offered for inspection. The middle 10 ft. of the sample shall be immersed in distilled water for a period of 14 days with the $2\frac{1}{2}$-ft. portion at each end kept above the water as leakage insulation. The three measurements specified in Section 20 shall be taken with the water at the same temperature. The water shall be maintained at room temperature, but not less than 70 F. (21 C.).

(*b*) The specific inductive capacity of the insulation shall be determined at commercial frequencies and shall be calculated as follows:

$$\text{Specific inductive capacity} = 13{,}600\, C \log_{10} \frac{D}{d}$$

where C = the capacity in microfarads of 10 ft. of sample;
D = the diameter over insulation; and
d = the diameter over conductor.

The moisture absorption test shall be made only when requested by the purchaser.

(*C*) CABLE TAPE

Material

53. Cable tape shall be made from cotton cloth having a weight of not less than 1 lb. per 4 yd. with a width of 36 in. and not less than 56 by 60 picks per inch, and shall be frictioned on both sides and thoroughly filled with a rubber compound. The nominal thickness shall be 0.012 in. and not less than 0.011 in.

Application

54. The tape shall be applied helically and may be applied before vulcanization. The maximum width and minimum overlap shall conform to the values in Table VII.

Intermediate Diameters

55. For intermediate diameters the requirements shall be those of the next smaller diameter indicated in Table VII.

Number of Tests

56. Samples shall be taken at the option of the purchaser.

(*D*) COTTON BRAID

Braids

57. (*a*) Two types of cotton braid are covered in these specifications, namely, standard braid and heavy braid, as follows:

Standard Braid is designed for indoor service and installation in conduits.

Heavy Braid is designed for outdoor and rough service.

(*b*) Unless otherwise specified, standard braid shall be supplied under these specifications.

Material

58. Cotton braid shall be closely woven from cotton thread having not less than two plies.

TABLE VII.—WIDTH AND OVERLAP OF RUBBER-FILLED CABLE TAPE.

DIAMETER OVER INSULATION, IN.	MAXIMUM WIDTH OF TAPE, IN	MINIMUM OVERLAP, IN.
2.00	5	$\frac{1}{2}$
1.75	$4\frac{1}{2}$	$\frac{1}{2}$
1.50	4	$\frac{1}{2}$
1.25	$3\frac{1}{2}$	$\frac{1}{2}$
1.15	$3\frac{1}{4}$	$\frac{1}{2}$
1.00	3	$\frac{1}{2}$
0.88	$2\frac{3}{4}$	$\frac{3}{8}$
0.75	$2\frac{3}{8}$	$\frac{3}{8}$
0.62	2	$\frac{3}{8}$
0.50	$1\frac{3}{4}$	$\frac{3}{8}$
0.38	$1\frac{1}{2}$	$\frac{1}{4}$
0.31	$1\frac{1}{4}$	$\frac{1}{4}$
0.25	1	$\frac{1}{4}$
0.19	$\frac{7}{8}$	$\frac{3}{16}$
0.16	$\frac{3}{4}$	$\frac{3}{16}$

TABLE VIII.—TANGENT OF ANGLE OF BRAID.

DIAMETER UNDER BRAID, IN	VALUE OF TANGENT	CORRESPONDING BRAID ANGLE, DEG
0 to 1.00	0.700	35
1.001 to 1 500	0.839	40
1.501 and over	1.000	45

Construction

59. (*a*) The braid shall be so constructed that the tangent of the angle between the cotton thread and the side of the wire shall be not less than that specified in Table VIII.

(*b*) The thickness of standard braid shall be not less than that specified in Table IX and that of heavy braid not less than that specified in Table X.

(*c*) The number of carriers and the number of ends per carrier used in applying the braid shall be optional providing all other limitations of Sections 58 and 59 are met. However, the picks per inch shall be not less than the value as calculated by the following formula:

$$P = \sqrt{\left[\frac{1}{tE + M}\right]^2 - \left[\frac{C}{2\pi\,(D + T)}\right]^2}$$

where P = the picks per inch;

T = the thickness of braid, in inches; $T = 2t$

t = the thickness of one end of cotton, in inches; $t = \dfrac{0.0279\,K}{\sqrt{S}}$

K = cabling factor for plied yarn; values of K are: $\begin{cases} 2 \text{ ply} = 1.60 \\ 3 \text{ ply} = 2.00 \\ 4 \text{ ply} = 2.36 \end{cases}$

S = the cotton ply, size or number;

E = the number of ends per carrier;

TABLE IX.—MINIMUM THICKNESS OF STANDARD BRAID.

DIAMETER UNDER BRAID, IN.	MINIMUM THICKNESS OF BRAID, IN.	CORRESPONDING MINIMUM SIZE AND PLY OF COTTON YARN
0 to 0.200	0.0163	30/2
0.201 to 0.350	0.0175	26/2
0.351 to 0.800	0.0200	20/2
0.801 to 1.500	0.0258	12/2
1.501 to 3.000	0.0316	8/2

TABLE X.—MINIMUM THICKNESS OF HEAVY BRAID.

DIAMETER UNDER BRAID, IN.	MINIMUM THICKNESS OF BRAID, IN.	CORRESPONDING MINIMUM SIZE AND PLY OF COTTON YARN
0 to 0.200	0.020	20/2
0.201 to 0.300	0.0223	16/2
0.301 to 0.600	0.0258	12/2
0.601 to 1.000	0.0316	8/2
1.001 to 1.500	0.037	6/2
1.501 to 2.000	0.0446	4/2
2.001 to 3.000	0.0556	4/3

C = the number of carriers;

D = the diameter under braid, in inches;

M = the space between each set of carrier threads, in inches;

$$M = X\,(0.011 + 7.0\,t^2E^2)$$

X = the closeness constant { Values of X:

Values of X	DIAMETER UNDER BRAID, IN.
1.1	0 to 0.500
1.0	0.501 and over

For convenience in calculating the more usual braid constructions, the formula for picks may be reduced to:

$$P = \sqrt{Y - \frac{Z}{(D + T)^2}} \text{ where } Y = \frac{1}{(tE + M)^2} \text{ and } Z = \left(\frac{C}{2\pi}\right)^2$$

Values of Y for some of the most commonly used cottons are:

Size of Yarn	Thickness of Braid, *T*	Values of *Y*										
		For Diameters Under 0.500 in.				For Diameters 0.501 in. and Over						
		2 End	3 End	4 End	5 End	2 End	3 End	4 End	5 End	6 End	7 End	8 End
30/2	0.0163	1081	592	358	233	....	....	....	....	....	....	....
26/2	0.0175	982	526	312	220	....	....	....	....	....	....	....
24/2	0.0182	930	492	290	185	....	....	....	....	....	....	....
20/2	0.0200	807	416	241	151	878	446	259	163	....	....	....
16/2	0.0223	683	339	193	118	738	365	207	127	....	....	....
14/2	0.0238	616	302	168	103	664	324	180	111	....	....	....
12/2	0.0258	538	257	142	85	582	276	152	92	59	40	28
10/2	0.0282	....	....	....	....	497	231	125	74	48	32	22
8/2	0.0316	....	....	....	....	407	183	96	56	35	23	16

Values of *Z* for the standard braiders are:

NUMBER OF CARRIERS	VALUES OF *Z*
12	3.65
16	6.49
20	10.13
24	14.59
36	32.80
48	58.40

(*d*) For braid over twin wires use 1.64 times the conductor diameter to determine the proper braid.

(*e*) Where two braids are specified, the outer braid shall be determined by the diameter over the inner braid. Where the diameter change-over limit is such that Table IX or Table X and this section require different sizes of yarn on the inner and outer braids, both braids may be of the size of yarn as required on the outer braid.

(*f*) Where two braids are applied in one operation, these specifications shall apply to the inner and outer braids except that picks per inch and angle of braid for inner braid shall be governed by the construction of the machine.

(*g*) These specifications do not apply to braids for fixture wire or to fancy or special braids.

(*h*) In Table XI are tabulated the required picks per inch as calculated by the formula in Paragraph (*c*) and the corresponding braid angle for braids applied with the minimum size and ply of cotton, and a definite number of ends per carrier. However, it is not the intent of these specifications to limit the braids to the scope of Table XI since heavier cottons or a variation in ends per carrier are permissible providing all requirements of Sections 58 and 59 are fulfilled.

Measurements

60. The various quantities shall be determined as follows:

Diameter Under Braid, by a suitable micrometer reading.

Number of Carriers and *Ends per Carrier*, by examination of braid.

TABLE XI.—BRAID.

Diameter Under Braid, D, in.	Size and Ply of Cotton Yarn, Minimum	No. of Ends	Thickness of Braid, Minimum, in.	Diameter, Mean Avg. $(D+T)$, in.	12-Carrier Braiders		16-Carrier Braiders		20-Carrier Braiders		24-Carrier Braiders		36-Carrier Braiders		48-Carrier Braiders	
					Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.	Picks per inch	Braid Angle, deg.
STANDARD BRAID																
0.090..........	30/2	2	0.0163	0.106	27.7	57.0	22.6	43.0	....	....	....	....	....	....	....	....
0.091 to 0.110..........	30/2	2	0.0163	0.116	28.6	60.0	24.7	48.0	....	....	....	....	....	....	....	....
0.111 to 0.125..........	30/2	2	0.0163	0.134	29.8	65.0	27.0	55.0	23.0	44.0	....	....	....	....	....	....
0.126 to 0.150..........	30/2	2	0.0163	0.154	30.6	68.0	28.6	60.0	25.8	51.0	....	....	....	....	....	....
0.151 to 0.175..........	30/2	2	0.0163	0.179	31.2	71.0	29.8	64.0	27.8	58.0	....	....	....	....	....	....
0.176 to 0.200..........	30/2	2	0.0163	0.204	31.6	73.0	30.6	68.0	29.1	62.0	....	....	....	....	....	....
0.201 to 0.225..........	26/2	2	0.0175	0.231	30.2	74.3	29.3	69.4	28.1	63.9	26.6	58.1	....	....	....	....
0.226 to 0.250..........	26/2	2	0.0175	0.256	30.4	76.2	29.7	71.5	28.8	66.7	27.6	61.6	....	....	....	....
0.251 to 0.300..........	26/2	2	0.0175	0.293	30.4	78.0	30.2	74.0	29.5	70.0	28.6	65.0	....	....	....	....
0.301 to 0.350..........	26/2	2	0.0175	0.343	....	....	....	....	30.0	73.0	29.4	69.0	....	....	....	....
0.351 to 0.400..........	20/2	3	0.020	0.396	....	....	....	....	18.8	66.0	18.0	62.0	....	....	....	....
0.401 to 0.450..........	20/2	3	0.020	0.445	....	....	....	....	19.1	70.0	18.5	65.0	....	....	....	....
0.451 to 0.500..........	20/2	3	0.020	0.495	....	....	....	....	19.4	72.0	18.9	68.0	....	....	....	....
0.501 to 0.600..........	20/2	3	0.020	0.570	....	....	....	....	20.4	75.0	20.1	72.0	....	....	....	....
0.601 to 0.800..........	20/2	3	0.020	0.720	....	....	....	....	20.6	78.0	20.5	76.0	....	....	....	....
0.801 to 1.000..........	12/2	4	0.0258	0.925	....	....	....	....	11.8	73.7	11.6	70.3	10.7	59.8	9.2	48.0
1.001 to 1.200..........	12/2	4	0.0258	1.125	....	....	....	....	12.0	76.8	11.9	74.0	11.2	65.7	10.3	56.6
1.201 to 1.500..........	12/2	4	0.0258	1.376	....	....	....	....	....	....	12.0	77.0	11.6	70.2	11.0	63.2
1.501 to 2.000..........	8/2	5	0.0316	1.782	....	....	....	....	....	....	6.2	73.3	6.8	64.6	6.1	55.0
2.001 to 3.000..........	8/2	5	0.0316	2.532	....	....	....	....	....	....	7.3	78.2	7.1	72.2	6.9	66.2
HEAVY BRAID																
0.090..........	20/2	2	0.020	0.110	22.6	52.5	16.5	35.5	....	....	....	....	....	....	....	....
0.091 to 0.110..........	20/2	2	0.020	0.120	23.6	56.0	18.9	41.7	....	....	....	....	....	....	....	....
0.111 to 0.125..........	20/2	2	0.020	0.138	24.6	58.3	21.5	49.3	....	....	....	....	....	....	....	....
0.126 to 0.150..........	20/2	2	0.020	0.158	25.7	64.6	23.3	55.3	20.0	44.8	....	....	....	....	....	....
0.151 to 0.175..........	20/2	2	0.020	0.183	26.4	67.5	24.8	60.5	22.7	52.5	19.2	42.5	....	....	....	....
0.176 to 0.200..........	20/2	2	0.020	0.208	26.9	70.4	27.5	65.8	23.7	57.0	21.6	49.5	....	....	....	....
0.201 to 0.225..........	16/2	2	0.0223	0.235	....	....	23.8	56.5	22.4	58.8	20.4	51.5	....	....	....	....
0.226 to 0.250..........	16/2	2	0.0223	0.260	....	....	25.8	77.8	23.0	62.0	21.6	55.6	....	....	....	....
0.251 to 0.300..........	16/2	3	0.0223	0.297	....	....	16.3	62.3	15.0	54.5	13.2	49.5	....	....	....	....
0.301 to 0.350..........	12/2	3	0.0258	0.351	....	....	....	....	13.2	55.4	11.8	47.3	....	....	....	....
0.351 to 0.400..........	12/2	3	0.0258	0.401	....	....	....	....	13.9	60.1	12.9	53.5	....	....	....	....
0.401 to 0.450..........	12/2	3	0.0258	0.451	....	....	....	....	14.4	63.9	13.6	58.1	....	....	....	....
0.451 to 0.500..........	12/2	3	0.0258	0.501	....	....	....	....	14.7	66.6	14.1	62.0	....	....	....	....
0.501 to 0.600..........	12/2	3	0.0258	0.576	....	....	....	....	....	....	15.2	66.4	13.3	55.7	....	....
0.601 to 0.800..........	8/2	3	0.0316	0.732	....	....	....	....	....	....	12.5	67.3	11.1	57.2	....	....
0.801 to 1.000..........	8/2	3	0.0316	0.932	....	....	....	....	....	....	12.9	72.3	12.0	65.0	10.8	53.0
1.001 to 1.200..........	6/2	2	0.037	1.137	....	....	....	....	....	....	....	....	17.0	74.9	16.4	67.7
1.201 to 1.500..........	6/2	2	0.037	1.387	....	....	....	....	....	....	....	....	17.2	77.7	16.8	71.8
1.501 to 2.000..........	4/2	3	0.0446	1.795	....	....	....	....	....	....	....	....	8.6	71.3	8.1	62.3
2.001 to 3.000..........	4/3	3	0.0556	2.556	....	....	....	....	....	....	....	....	6.6	72.8	6.3	64.5

Picks per Inch, on a 4-in. sample after wiping off outside of braid with chloroform.

Angle of Braid by formula: $\text{Tangent of Angle} = \dfrac{2\pi P\,(D + T)}{C}$

Thickness of Braid (2 × diameter of single end of cotton), by measuring 25 per cent of the total number of threads with a paper micrometer having a foot 0.4 in. in diameter under a weight of 50 g. The sample of braid on which the average diameter is determined shall be prepared by immersing a 2-in. length of sample in chloroform in a suitable container for 5 minutes, decanting and repeating for 1 minute, and removing and drying it thoroughly by pressing it between cheese cloth.

Number of Tests

61. Samples shall be taken at the option of the purchaser.

(*E*) FINISH

Finish

62. The braid shall be completely saturated and finished with a black moisture-resistant compound. The surface of the wire shall be smooth and free from tackiness. The finish shall be capable of meeting the tests described in Sections 63 to 67, inclusive.

Bend Test

63. (*a*) *Sample.*—Each sample for the bend test shall be wrapped as specified in Paragraph (*b*) around a mandrel of the diameter given in the following table:

Size of Wire or Cable, A.w.g. Numbers or Circular Mils	Ratio of Mandrel Diameter to Outside Diameter of Wire or Cable
No. 14 to No. 12	1½
No. 10 to No. 8	2¼
No. 6 to No. 2	3
No. 1 to No. 0000	4½
250 000 to 500 000 cir. mils	6
550 000 to 1 000 000 cir. mils	9
1 250 000 to 2 000 000 cir. mils	10½

(*b*) *Test Procedure.*—The samples shall be held at a temperature of 32 F. (0 C.) for approximately 1 hr. before bending, and upon removal from the cooling chamber shall be wrapped upon the mandrel at an approximately uniform rate not greater than 12 turns per minute. Single conductor No. 2 A.w.g. and smaller shall be wrapped three times around the mandrel; when requested single conductor wires larger than No. 2 A.w.g. and any multiple conductor shall be wrapped once around the mandrel.

(*c*) *Flaking and Cracking.*—The finishing material shall not flake off the wire or cable during the bend test or as a result of the bend test without actually rubbing the surface of the wire. Cracking of the finish will not be cause for rejection.

Melt Test

64. A piece of clean white glazed paper shall be wrapped around a 6-in. sample of finished wire or cable and this shall be suspended hori-

zontally in an electrically heated oven, equipped with suitable automatic temperature control, which has been heated to 125 F. (52 C.) and the wire or cable shall be maintained at this temperature for 30 min. The wire or cable with the paper wrapping shall be cooled before inspection. The wire shall be rejected if the compound becomes sufficiently fluid to be transferred to the paper or form a ridge perceptible to the finger upon it.

Drip Test

65. Samples for the drip test shall be cut in lengths of 6 in. and the wire bared for a distance of ¾ in. from each end. The sample with one end secured in a suitable clamp shall then be suspended at an angle of 45 deg. in an electrically heated oven, equipped with suitable automatic temperature control, which has been heated to 180 F. (82.2 C.) and the wire or cable shall be maintained at this temperature for 1 hr. At the end of this time the compound shall not have dripped, flowed onto the surface of the lower bared end of the conductor, formed globules on the lower side of the sample or bubbles upon its surface.

Moisture Absorption Test

66. (*a*) The moisture absorption shall not exceed 15 per cent when determined in accordance with Paragraphs (*b*) and (*c*).

(*b*) *Sample.*—A sample of finished wire, 24 in. in length, shall be bent around a mandrel, the diameter of which shall be determined from the over-all diameter of the wire, as follows:

SIZE OF WIRE OR CABLE, A.W.G. NUMBERS OR CIRCULAR MILS	DIAMETER OF MANDREL	BEND, DEG.
No. 14 to No. 12	1½ times diameter of wire	360
No. 10 to No. 8	2¼ times diameter of wire	360
No. 6 to No. 2	3 times diameter of wire	360
No. 1 to No. 0000	4½ times diameter of wire	180
250 000 to 500 000 cir. mils	6 times diameter of wire	180
550 000 to 1 000 000 cir. mils	9 times diameter of wire	180
1 250 000 to 2 000 000 cir. mils	10 times diameter of wire	180

As many turns as possible of sizes No. 2 A.w.g. and smaller shall be made about the mandrel, leaving the free ends of such length as to permit 2 in. of each end to be exposed when the samples are subsequently immersed. Sizes larger than No. 2 shall be bent in the form of a "U" about the mandrel specified.

(*c*) *Test Procedure.*—The flexed samples shall be removed from the mandrel and exposed in free air at room temperature for at least 48 hr. and then carefully weighed. This weight shall be recorded as W. The flexed samples shall then be immersed in distilled water at room temperature in such a manner that the flexed portion of the sample is completely covered with water and the free ends projecting not more than 2 in. above the surface of the water. The samples shall be allowed to remain immersed for a period of 72 hr. at room temperature. At the end of the immersion period the samples shall be removed, rinsed in pure alcohol for not over 5 sec., and allowed to dry in air for not over 5 min., to allow surface water to evaporate. Sizes No. 1 A.w.g. and larger may be dried by wiping with a dry cloth. The samples shall then be immediately weighed. This weight should be recorded as W_1. After weighing, all coverings shall be removed from the insulation and the conductor and insulation weighed. This weight shall be recorded as W_2.

(*c*) *Calculation of Results.*—The moisture absorbed in terms of percentage by weight of fibrous coverings shall be calculated by the following formula:

$$\text{Percentage Moisture Absorption} = \frac{100\,(W_1 - W)}{W - W_2}$$

Saturating and Finishing Compounds

67. The saturating and finishing compounds shall have no injurious effect upon the rubber insulation or the coverings during application.

TABLE XII.—THICKNESS OF LEAD SHEATHS.

DIAMETER OF CORE, IN.[a]	THICKNESS OF SHEATH IN SIXTY-FOURTHS OF AN INCH
Over 3.000	9
2.001 to 3.000	8
1.501 to 2.000	7
1.051 to 1.500	6
0.701 to 1.050	5
0.426 to 0.700	4
0.000 to 0.425	3

[a] For twin cables, use the major axis.

(*F*) LEAD SHEATHS

Composition

68. (*a*) Lead sheaths shall consist of Grade II Chemical Lead or Grade III Common Lead not less than 99.85 per cent pure as specified in the Standard Specifications for Pig Lead (A.S.T.M. Designation: B 29) of the American Society for Testing Materials.[1] It shall be obtained from properly branded pig lead.

(*b*) Lead sheaths shall be tightly formed around the core of the wire or cable.

Thickness

69. Lead sheaths shall have an average thickness not less than that indicated in Table XII and the minimum thickness shall in no place be less than 90 per cent of the required average thickness.

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[1] 1935 Supplement to Book of A.S.T.M. Standards, p. 26.

Measurement

70. A short section of the lead sheath shall be removed from the wire or cable and the thickness measured with a suitable micrometer caliper at not less than ten points, approximately equally spaced, care being taken to include the thinnest and the thickest parts.

(*G*) INSPECTION AND REJECTION

Inspection and Test

71. (*a*) Inspection shall be made prior to shipment and at the place of manufacture.

(*b*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the wire or cable to permit of arrangement of inspection.

(*c*) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wire ordered, except compounding room. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications.

(*d*) The purchaser at his option may make the various tests on samples in his own laboratory or elsewhere, but such tests shall be made at the expense of the purchaser.

Rejection

72. Each coil, reel or length which fails to comply with the physical and electrical requirements of these specifications shall be rejected.

Rehearing

73. Samples of rejected material shall be preserved for two weeks from date of test report. In case of dissatisfaction with the results of test, the manufacturer may make claim for a rehearing within that time. Sealed duplicate samples may be retained by the manufacturer at his option.

APPENDIX I

ANNEALED COPPER STANDARD[1]

The following shall be taken as normal values for standard annealed copper:

(*a*) *Resistance.*—At a temperature of 20° C. the resistance of a

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[1] Extracts from American Institute of Electrical Engineers' Standard No. 30 (1932).

wire of standard annealed copper 1 meter in length and of a uniform section of 1 sq. mm. is $\frac{1}{58}$ ohm = 0.017241 ohm.

(*b*) *Density.*—At a temperature of 20° C. the density of standard annealed copper is 8.89 g. per cu. cm.

(*c*) *Temperature Coefficient of Resistance.*—At a temperature of 20° C. the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per degree Centigrade.

(*d*) Other values of resistivity of standard annealed copper at 20° C. deduced from Paragraphs (*a*) and (*b*) are as follows:

Resistance of a wire of uniform section, 1 meter long and weighing 1 g. = 0.15328 ohm.

Resistance of a wire with a uniform section of 1 cir. mil and 1 ft. long = 10.371 ohm.

Resistance between opposite faces of 1 cu. cm. = 1.7241 microhm.

Resistance between opposite faces of 1 cu. in. = 0.67879 microhm.

APPENDIX II

INTERPRETATION OF INSULATION THICKNESSES OF TABLE IV

For series-street-lighting cable, use the following procedure:

(*a*) If the transformer is not equipped with protectors, use the open circuit secondary voltage of the transformer as rated voltage of the cable and select the proper wall thickness from Table IV.

(*b*) If the transformer is equipped with protectors, use the closed or loaded secondary voltage of the transformer as the rated circuit voltage of the cable and select the proper wall thickness from Table IV.

NOTE.—It is preferable, both in Paragraphs (*a*) and (*b*) above, to select a cable with a higher voltage rating than obtained using the above procedure, both as a measure of safety and to allow the substitution of a larger transformer without necessitating the replacement of the cable.

The thickness of insulation for the various systems shall be determined as follows:

(*a*) For three-phase systems with grounded or ungrounded neutral, use thickness values in accordance with Table IV.

(*b*) For single or two-phase systems up to and including 5000 v., use thickness values in accordance with Table IV.

TENTATIVE SPECIFICATIONS

FOR

INSULATED WIRE AND CABLE: PERFORMANCE RUBBER COMPOUND[1]

A.S.T.M. Designation: D 353 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1932; REVISED, 1933, 1934, 1935.[2]

Scope

1. (*a*) These specifications cover wire and cable insulated with a vulcanized rubber compound. The suitability of the compound as insulation shall be determined solely by physical and electrical tests. The compound shall be called performance rubber compound.

(*b*) Except for the rubber insulation and methods of testing, wire and cable supplied under these specifications shall conform to the Tentative Specifications for Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound (A.S.T.M. Designation: D 27 - 35 T) of the American Society for Testing Materials.[3]

INSULATION

Workmanship

2. (*a*) The insulation shall be homogeneous in character, tough, elastic and applied concentrically about the conductor and shall fit tightly thereto. Where the insulation is applied in more than one layer adjacent layers shall be vulcanized into a homogeneous mass.

(*b*) The insulation of braided wires up to No. 7 A. w. g., inclusive, shall be covered with a single cotton braid. On larger sizes the fibrous covering shall consist of a cable tape and cotton braid or two cotton braids. The cable tape may be applied before vulcanization. In multiple conductor cables the individual conductors shall not be braid-covered unless specified.

(*c*) Where repairs or joints are made in the insulation, the work shall be done in such manner that the repaired part of the joint, and all parts affected in the process, shall be as strong and durable electrically and mechanically as the remainder of the insulation and shall not exceed the limitations on the thickness specified in Section 5.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Latest revision accepted by Committee E-10 on Standards, September 28, 1935.

[3] See p. 1115.

MANUFACTURE

Composition

3. The insulation shall consist of a properly vulcanized rubber compound that will meet the tests hereinafter specified.

PHYSICAL PROPERTIES

Physical Properties

4. The insulation shall conform to the following requirements as to physical properties:

	MAXIMUM	MINIMUM
Tensile strength, lb. per sq. in.	..	1200
Tensile stress at 200 per cent elongation, lb. per sq. in.	..	300
Elongation at rupture, per cent	..	400
Set in 2-in. gage length, in.	$\frac{3}{8}$	....
Depreciation in tensile strength and elongation after oxygen bomb test, per cent	25	....
Depreciation in tensile strength and elongation after Geer oven test, per cent	15	....

THICKNESS

Thickness

5. (*a*) The average thickness of the insulation shall be not less than that given in Table I. The minimum thickness shall be not less than 95 per cent of the specified thickness for insulations less than $\frac{4}{64}$ in. and not less than 90 per cent of the specified thickness for insulations of $\frac{4}{64}$ in. and over.

(*b*) The thicknesses in Table I apply to single conductor cable and the individual conductors of multiple conductor cables, leaded or braided, except special applications such as aerial, non-leaded submarine, and vertical riser cable.

NOTE.—In Appendix I will be found an interpretation of the insulation thicknesses given in Table I.

ELECTRICAL PROPERTIES

High Voltage Test

6. Each coil, reel, or length of wire or cable after vulcanization shall successfully withstand the application of an alternating voltage of not less than that prescribed in Table I for a period of 5 minutes. (See Sections 30 and 31.)

Insulation Resistance

7. Each coil, reel, or length of wire or cable after being subjected to the high voltage test specified in Section 6 shall have an insulation resistance not less than that given in Table II.

TABLE I.—THICKNESS OF INSULATION AND ALTERNATING TEST VOLTAGE.

NOTE 1.—Rated circuit voltage of alternating-current circuits is the phase-to-phase voltage.

NOTE 2.—For an intermediate size of wire or an intermediate rated circuit voltage, the thickness and test voltage shall be that for the next larger size or higher rated circuit voltage.

NOTE 3.—For non-leaded submarine cables, $\frac{1}{32}$ in. should be added to the specified respective walls of insulation in this table for all sizes and voltages.

NOTE 4.—This table applies to wire for use on grounded and ungrounded circuits.

Rated Circuit Voltage	Size of Conductor, A. w. g. Numbers or Circular Mils	Insulation Thickness on each Conductor, sixty-fourths of an inch	Test Voltage
0 to 300	No. 18 to No. 16	2	1 000
0 to 600	No. 14 to No. 9	3	3 000
	No. 8 to No. 2	4	3 500
	No. 1 to No. 0000	5	4 000
	225 000 to 500 000 cir. mils	6	5 000
	525 000 to 1 000 000 cir. mils	7	6 000
	Over 1 000 000 cir. mils	8	7 000
601 to 1000	No. 14 to No. 8	4	5 000
	No. 7 to No. 2	5	6 000
	No. 1 to No. 0000	6	7 500
	225 000 to 500 000 cir. mils	7	9 000
	525 000 to 1 000 000 cir. mils	8	10 000
	Over 1 000 000 cir. mils	9	11 000
1001 to 2000	No. 14 to No. 8	5	6 000
	No. 7 to No. 2	6	7 500
	No. 1 to No. 0000	7	9 000
	225 000 to 500 000 cir. mils	8	10 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	9	11 000
2001 to 3000	No. 14 to No. 8	7	9 000
	No. 7 to No. 2	8	10 000
	No. 1 to No. 0000	8	10 000
	225 000 to 500 000 cir. mils	9	11 000
	525 000 to 1 000 000 cir. mils	9	11 000
	Over 1 000 000 cir. mils	10	12 500
3001 to 4000	No. 14 to No. 8	9	11 000
	No. 7 to No. 2	9	11 000
	No. 1 to No. 0000	9	11 000
	225 000 to 500 000 cir. mils	10	12 500
	525 000 to 1 000 000 cir. mils	10	12 500
	Over 1 000 000 cir. mils	11	13 500
4001 to 5000	No. 14 to No. 8	10	12 500
	No. 7 to No. 2	10	12 500
	No. 1 to No. 0000	10	12 500
	225 000 to 500 000 cir. mils	11	13 500
	525 000 to 1 000 000 cir. mils	11	13 500
	Over 1 000 000 cir. mils	12	15 000

Moisture Absorption.

8. (*a*) The increase in the specific inductive capacity of the insulation shall be used as an indication of the amount of moisture absorbed.

(*b*) The specific inductive capacity after 24-hr. immersion in water shall not exceed six. The increase between the ends of the first and the fourteenth days shall not exceed 20 per cent and that between the ends of the seventh and fourteenth days, 5 per cent.

(*c*) The specific inductive capacity shall be determined at either 1000 or 60 cycles. Where measured at 1000 cycles, the voltage impressed upon the conductor shall not exceed 10 volts. Where measured at 60 cycles, the voltage impressed upon the conductor shall be equivalent to a stress of between 30 to 40 volts per mil of insulation.

(*d*) The measurements shall be made as described in Section 35.

METHODS OF TESTING

TENSILE STRENGTH, SET, AND ELONGATION AT RUPTURE

Sampling for Physical Tests

9. (*a*) Wire up to and including 250,000 cir. mils in size shall be sampled in accordance with the following requirements:

	NUMBER OF SAMPLES
2000 ft. and under	none
2001 to 10,000 ft.	1 for each 2000 ft. or fraction thereof
10,001 to 100,000 ft.	5 plus 1 for each 10,000 ft. additional over 10,000 ft.
100,001 to 500,000 ft.	14 plus 1 for each 25,000 ft. over 100,000 ft.

(*b*) For wire larger than 250,000 cir. mils, one sample shall be selected from quantities between 1000 and 2000 ft. and for larger quantities double those specified in Paragraph (*a*).

Test Specimens

10. (*a*) *Size*.—For the physical tests, the test specimen may be the entire cross-section of the insulation in the case of small wires, or, in the case of a large wire or cable, either a segment or sector cut with a sharp knife held tangentially to the conductor or a shaped specimen cut out with a standard die. The test specimen shall be as free as possible from surface incisions and imperfections. There shall be no limit to the cross-section of the test specimen, except as restricted by the capacity of the testing machine.

NOTE.—The removal of the rubber insulation can be greatly accelerated and in most cases a test specimen which is an entire cross-section can be obtained free from surface incisions and imperfections by means of metallic mercury. The mercury should be introduced at one end of the sample between the insulation and the tinned surface of the conductor, and the sample inclined on a support with the end to which the mercury is applied at the top. The separation of the rubber insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury.

(*b*) *Condition and Age.*—Specimens shall not be heated, immersed in water or subjected to any mechanical or chemical treatment not specifically prescribed in these specifications.

Specimens for accelerated aging tests shall be taken from the completed wire after the application of the specified covering and shall be aged with all such covering removed.

TABLE II.—INSULATION RESISTANCE, MEGOHMS-1000 FT. AT 60° F. (15.5° C.).

NOTE 1.—This table is based on a constant, $K = 21\,120$ in the following formula:

$$R = K \log_{10}\frac{D}{d}$$; where R = resistance in megohms-1000 ft., K = constant,

D = diameter over insulation, on each conductor, and d = diameter over conductor.

NOTE 2.—For an intermediate size, the insulation resistance shall be that of the next larger size.

Size of Conductor, A. w. g. Numbers or Circular Mils	Solid or Stranded	Diameter in Inches	Insulation Thickness in Sixty-fourths of an Inch									
			2	3	4	5	6	7	8	9	10	12
No. 18	Solid	0.040	8 600	11 100	....	....	....	....	....	....	....	....
No. 16	Solid	0.051	7 300	9 500	....	....	....	....	....	....	....	....
No. 14	Solid	0.064	....	8 300	9 900	11 300	12 550	13 650	14 600	15 450	16 250	17 650
No. 12	Solid	0.081	....	7 050	8 550	9 850	11 000	12 000	12 900	13 750	14 500	15 850
No. 10	Solid	0.102	....	6 000	7 350	8 500	9 600	10 500	11 350	12 100	12 850	14 150
No. 8	Solid	0.128	....	....	6 200	7 300	8 300	9 150	9 950	10 650	11 350	12 550
No. 6	Stranded	0.184	....	....	4 750	5 600	6 400	7 200	7 900	8 500	9 100	10 200
No. 4	Stranded	0.232	....	....	3 900	4 700	5 450	6 100	6 700	7 250	7 800	8 850
No. 2	Stranded	0.292	....	....	3 250	3 900	4 550	5 150	5 650	6 150	6 650	7 600
No. 1	Stranded	0.332	....	....	....	3 550	4 100	4 650	5 150	5 600	6 100	6 950
No. 0	Stranded	0.373	....	....	....	3 200	3 750	4 200	4 700	5 150	5 550	6 350
No. 00	Stranded	0.418	....	....	....	2 900	3 400	3 850	4 300	4 700	5 100	5 850
No. 000	Stranded	0.470	....	....	....	2 600	3 100	3 500	3 900	4 250	4 650	5 400
No. 0000	Stranded	0.528	....	....	....	2 400	2 800	3 150	3 550	3 900	4 200	4 900
250 000 cir. mils	Stranded	0.575	....	....	....	....	2 600	2 950	3 300	3 650	4 000	4 600
350 000 cir. mils	Stranded	0.681	....	....	....	....	2 250	2 550	2 850	3 150	3 450	4 000
500 000 cir. mils	Stranded	0.814	....	....	....	....	1 900	2 200	2 450	2 700	2 950	3 450
750 000 cir. mils	Stranded	0.998	....	....	....	....	....	1 800	2 050	2 250	2 500	2 900
1 000 000 cir. mils	Stranded	1.152	....	....	....	....	....	1 600	1 800	2 000	2 200	2 600
1 250 000 cir. mils	Stranded	1.289	....	....	....	....	....	....	1 600	1 800	2 000	2 350
1 500 000 cir. mils	Stranded	1.412	....	....	....	....	....	....	1 500	1 650	1 850	2 150
1 750 000 cir. mils	Stranded	1.526	....	....	....	....	....	....	1 400	1 550	1 700	2 000
2 000 000 cir. mils	Stranded	1.631	....	....	....	....	....	....	1 300	1 500	1 600	1 900

No tests shall be made within 24 hours nor later than 60 days after vulcanization unless agreed to by the manufacturer.

(*c*) *Buffing.*—In the event of any irregularities on the surface of the test specimen, it shall be made smooth and of uniform thickness within 5 per cent of the original thickness by buffing, except when large strands are used, in which case the rubber sample shall be buffed sufficiently to remove all corrugations.

Calculation of Area

11. Calculation of the area of the test specimens shall be made as follows:

(*a*) Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the conductor. The area of the stranded conductor shall be calculated from its maximum diameter.

(*b*) Where a segment or sector of the insulation has to be taken in the case of a large wire or cable or where the insulation is thin, the area shall be calculated as the thickness times the width. (This applies either to a straight test specimen or one stamped out with a die, and assumes that corrugations have been removed by buffing.)

Temperature at Test

12. Physical tests shall be made at a room temperature not less than 65° F. (18.3° C.) nor more than 90° F. (32.2° C.) and the test specimen shall have been kept at the room temperature not less than 30 minutes prior to the test.

Tension Testing Machine

13. The tension testing machine shall be power-driven and preferably of the pendulum type. The machine shall be accurate within 1 per cent of the breaking load. A spring balance type of apparatus may be used if provided with a device which will indicate the actual maximum load at which rupture takes place and if provision is made to prevent recoil of the spring.

Tensile Strength Tests

14. The tensile strength test shall be made on a specimen which has not been previously stretched. The specimen shall have a length of not less than 6 in., and shall be marked with gage marks 2 in. apart and placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. The specimen shall be stretched at the rate of 20 in. per minute (jaw speed) until it breaks. The test specimen shall break between the gage marks. The tensile strength shall be calculated upon the area of the original specimen.

Tensile Stress Test

15. The tensile stress test shall be made simultaneously with the tensile strength test by recording the load when the 2-in. gage length marks are 6 in. apart, that is, at 200 per cent elongation. The tensile stress shall be calculated upon the area of the original specimen.

Elongation at Rupture

16. Elongation at rupture shall be determined simultaneously with the tensile strength test by reading the distance in inches between gage marks at the breaking point. The elongation at rupture shall be taken as the distance between gage marks at rupture less 2 in.

(the original gage length). The percentage of elongation at rupture is the elongation in inches divided by the original gage length (2 in.) and multiplied by 100 to express as a percentage.

Set Test

17. The set test shall be made on a separate test specimen having a length of not less than 6 in. and marked with gage marks 2 in. apart. The specimen shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. and shall be stretched at the rate of 20 in. per minute (jaw speed) until the gage marks are 6 in. apart. The test specimen shall then be released within 5 seconds and the distance between gage marks shall be determined 1 minute after the beginning of release. The set is the difference between this length and the original 2-in. gage length.

Retests, Physical Properties

18. Where tested in accordance with Sections 14, 15, 16 and 17, if a specimen fails to conform to any one of the requirements for tensile strength, tensile stress, set, or elongation at rupture specified in Section 4, two additional specimens shall be taken from the same sample and tested, and the average of the results shall determine whether the material conforms to the requirements.

AGING TESTS

Sampling for Aging Tests

19. For aging tests the wire shall be sampled as follows:

No samples shall be selected where the quantity is less than 2000 ft. of wire or cable.

For sizes less than 250,000 cir. mils one sample shall be selected for each quantity ordered between 2000 ft. and 50,000 ft. of wire or cable and one additional sample for each additional 50,000 ft. thereafter.

For sizes 250,000 cir. mils and over one sample shall be selected for each quantity ordered between 2000 ft. and 25,000 ft. of wire or cable and one additional sample for each additional 25,000 ft. thereafter.

Test Specimens

20. Nine test specimens of similar size and shape shall be prepared from each sample selected in accordance with Section 19, three for the determination of the initial or unaged properties, three for the oxygen bomb test and three for the Geer oven test. One specimen of each three shall be tested and the other two held as spares except that where only one sample is selected all three specimens shall be tested and the average of the results reported.

Aging Test Conditions

21. (*a*) In the case of wire and cable smaller than No. 6 A.w.g. with an insulation thickness less than $\frac{3}{32}$ in., the insulation shall be heated in the oxygen bomb and in the Geer oven without removing the conductor.

(*b*) In the case of wire and cable of No. 6 A.w.g. and larger or with an insulation thickness greater than $\frac{3}{32}$ in., samples approximately square in section shall be cut from the insulation with a cross-section not greater than 0.025 sq. in.

(*c*) Die-cut samples shall be buffed before being subjected to the accelerated aging test wherever the thickness of the sample is $\frac{3}{32}$ in. or greater after buffing.

(*d*) The test specimens shall have no protective covering and shall be suspended vertically in such a manner that they will not come in contact with each other or with the sides of the bomb or oven.

(*e*) Physical tests on both the aged and unaged specimens shall be made at the same time. The aged specimens shall have a rest period of not less than 16 hours nor more than 48 hours between the completion of the aging test and determination of physical properties.

(*f*) Should the first set of specimens selected under Paragraph (*a*) fail to meet the specifications, two other sets of specimens shall be tested and if either of these sets fails, the coils, reels or lengths will be rejected.

Oxygen Bomb Test

22. The test specimens shall be heated in an atmosphere of oxygen at a pressure of 300 lb. per sq. in. at a temperature of from 157 to 159° F. for a period of 96 hours. The weight of the rubber in the bomb shall not be over 2 g. per cu. in. of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least two minutes, when specimens are removed. The bomb temperature shall be recorded automatically on a chart.

Geer Oven Test

23. The test specimens shall be heated at a temperature of from 157 to 159° F. for a period of 96 hours in an oven having a free circulation of fresh air. The oven temperature shall be recorded automatically on a chart.

Rejection

24. Where ten or more samples are selected in any inspection lot, all coils, reels or lengths shall be rejected if more than 10 per cent of the samples fail. If 10 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the results of

such individual tests. Where the number of samples selected in any inspection lot is less than ten, all coils, reels or lengths shall be rejected if more than 20 per cent of the samples fail. If 20 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the results of such individual tests.

THICKNESS MEASUREMENTS

Apparatus

25. The thickness measurements may be made with any type of micrometer reading to 0.001 in., suitable for measurements of this character.

Number of Measurements

26. Where the lot of wire to be inspected consists of two coils or reels or less, at least one determination of the thickness shall be made on each coil or reel. Where the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, not less than 10 per cent of the coils or reels shall be selected at random and at least one determination of the thickness made on each coil or reel so selected.

Procedure

27. The average thickness of the insulation shall be taken as one-half the difference between the mean of the maximum and minimum diameters measured at any point and the average diameter of the conductor measured at the same point. The minimum thickness shall be as taken the difference between a measurement made over the conductor plus the thinnest wall and the diameter of the conductor. (The first measurement is made by "slicing off" the heavier side of the insulation.)

In the case of multiple-conductor cable, the measurements shall be made on the individual wires before being cabled.

Rejection

28. If the thickness of the insulation of any coil or reel is found to be less than the specified value, that coil or reel shall be rejected and a thickness measurement on each of the remaining coils or reels shall be made.

ELECTRICAL TESTS

Place

29. Electrical tests of wire and cable shall be made at the place of manufacture.

High Voltage Test

30. The high voltage test shall be made with alternating potential from a transformer and generator of ample capacity and in no case less than 5 kva. The frequency of the test voltage shall be not greater than 100 cycles and shall have a wave shape approximating as closely as possible a sine curve

Rate of Application

31. The initially applied voltage shall be not greater than the rated voltage and the rate of increase shall be approximately uniform and not over 100 per cent in 10 seconds nor less than 100 per cent in 60 seconds.

High Voltage Testing

32. (*a*) *General.*—Where insulated conductors are subjected to a high voltage test in water they shall be immersed in a grounded water bath and tested while still immersed.

(*b*) *Single Conductor.*—Single conductors shall be tested after 12 hr. immersion and without covering except a tape or braid applied before vulcanization.

Rubber sheathed conductors shall be immersed and tested after the sheath is applied.

Where a metallic sheath is applied, the conductors shall be retested against the sheath.

(*c*) *Multiple Conductor.*—The individual conductors of multiple conductor cables shall be tested before assembling as prescribed in Paragraph (*b*).

After assembly each conductor shall be tested against the adjacent conductors. Where a metallic sheath is applied each conductor shall in addition be tested against the sheath.

Cables having a rubber or other non-metallic waterproof sheath shall be immersed for 12 hr. and the conductors tested against ground. Cables covered with cable tape and braid or double braid with a weather-resistant finish shall not be immersed for testing.

Application of Voltage

33. (*a*) *Single-Conductor Cables.*—Single-conductor cables shall be tested between conductor and sheath or water in which they are immersed.

(*b*) *Multiple-Conductor Cables.*—If a multiple-conductor cable is rated at the same operating voltage between conductor and sheath or water as between conductors, each conductor shall be tested against the other conductors in the cable and against the sheath or water, at the test voltage prescribed for that rated voltage. If a cable is rated at a voltage between conductors and ground different from that between conductors, the test between conductors shall be made at the test voltage prescribed for the rated voltage between conductors and the test between each conductor and sheath or water, shall be made at the test voltage prescribed for the rated voltage between conductors and sheath or water.

The several tests may be made by any arrangement of testing transformers suitable for the prescribed tests, such as one or more transformers supplied from a single-phase source or three transformers connected in star and supplied from a three-phase source.

Insulation Resistance

34. (*a*) The insulation resistance shall be measured after the high voltage test has been made and while the wire or cable is still immersed in water. The measurement shall be made after one minute electrification with a continuous e.m.f. of from 100 to 500 volts, the conductor being maintained negative to the water. The temperature of the water shall be within the limits given in Table III.

TABLE III.—TEMPERATURE COEFFICIENTS.

Temperature		Temperature Coefficient	Temperature		Temperature Coefficient
Deg. Fahrenheit	Deg. Centigrade		Deg. Fahrenheit	Deg. Centigrade	
46	7.8	0.69	61	16.1	1.03
47	8.3	0.71	62	16.7	1.05
48	8.9	0.73	63	17.2	1.08
49	9.4	0.75	64	17.8	1.11
50	10.0	0.77	65	18.3	1.14
51	10.6	0.79	66	18.9	1.17
52	11.1	0.81	67	19.4	1.20
53	11.7	0.83	68	20.0	1.23
54	12.2	0.85	69	20.6	1.26
55	12.8	0.88	70	21.1	1.30
56	13.3	0.90	71	21.7	1.33
57	13.9	0.92	72	22.2	1.37
58	14.4	0.94	73	22.8	1.40
59	15.0	0.97	74	23.3	1.44
60	15.6	1.00	75	23.9	1.48

Temperature Coefficient

(*b*) If the temperature at which the insulation resistance was measured differs from 60° F. (15.6° C.), the resistance shall be reduced to that at 60° F. (15.6° C.) by multiplying the measured value by the coefficient in Table III corresponding to the temperature at which the measurement was made.

Moisture Absorption Test

35. (*a*) A 15-ft. sample with all the coverings removed shall be selected at random from the wire offered for inspection. The middle

10 ft. of the sample shall be immersed in distilled water for a period of 14 days with the $2\frac{1}{2}$-ft. portion at each end kept above the water as leakage insulation. The three measurements specified in Section 8 shall be taken with the water at the same temperature. The water shall be maintained at room temperature but not less than 70° F. (21° C.).

(*b*) The specific inductive capacity of the insulation shall be determined at commercial frequencies and shall be calculated as follows:

$$\text{Specific inductive capacity} = 13\,600\, C \log_{10} \frac{D}{d}$$

where C = the capacity in micro-farads of 10 ft. of sample;
D = the diameter over insulation; and
d = the diameter over conductor.

The moisture absorption test shall be made only when requested by the purchaser.

Rejection

36. Each coil, reel or length which fails to comply with the electrical requirements of these specifications shall be rejected.

APPENDIX I

INTERPRETATION OF INSULATION THICKNESSES OF TABLE I

For series-street-lighting cable, use the following procedure:

(*a*) If the transformer is not equipped with protectors, use the open circuit secondary voltage of the transformer as rated voltage of the cable and select the proper wall thickness from Table I.

(*b*) If the transformer is equipped with protectors, use the closed or loaded secondary voltage of the transformer as the rated circuit voltage of the cable and select the proper wall thickness from Table I.

NOTE.—It is preferable, both in Paragraphs (*a*) and (*b*) above, to select a cable with a higher voltage rating than obtained using the above procedure, both as a measure of safety and to allow the substitution of a larger transformer without necessitating the replacement of the cable.

The thickness of insulation for the various systems shall be determined as follows:

(*a*) For three-phase systems with grounded or ungrounded neutral, use thickness values in accordance with Table I.

(*b*) For single or two-phase systems up to and including 5000 v., use thickness values in accordance with Table I.

TENTATIVE METHODS OF PHYSICAL TESTING OF RUBBER PRODUCTS (GENERAL REQUIREMENTS)[1]

A.S.T.M. Designation: D 15 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These general methods of testing are intended to apply to soft vulcanized rubber compounds such as are used for the lining and cover of hose and belting, for carcass and tread of tires, and for a wide variety of molded or extruded rubber products. They do not apply without modification to the testing of that material ordinarily classed as hard rubber.

(*b*) Only instructions for preparation of test specimens of rubber products and the general requirements for approved testing are included in these general methods. Standard methods for individual test procedures are provided separately or in specifications covering a particular material.

(*c*) In case of conflict between the provisions of these methods and those of the individual test procedures or specifications for a particular material, the latter shall take precedence.

Place of Test

2. Tests shall be made at the place of manufacture, unless otherwise specified. The manufacturer shall provide the requisite facilities for conducting tests, including labor and equipment.

Sampling

3. (*a*) Samples shall be obtained, if possible, from the product to be tested and in such case shall be selected in accordance with the requirements of the specifications covering the particular material.

(*b*) In case it is not practicable to obtain suitable test specimens from the finished article, the manufacturer shall, upon request, furnish pieces 6 by 6 by 0.075 in. which he guarantees to be of the same material and equivalent cure as that used in the article.

Preparing Samples of Vulcanized Rubber

4. In case samples of vulcanized rubber are to be prepared for purpose

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

These tentative methods, together with the Tentative Methods of Tension Testing of Vulcanized Rubber (D 412 - 35 T), see p. 1159, and for Adhesion of Vulcanized Rubber (Friction Test) (D 413 - 35 T), see p. 1173, replace the Standard Methods of Physical Testing of Rubber Products (A.S.T.M. Designation: D 15 - 32), which standard was accordingly discontinued in 1935.

of tests from the compounding ingredients, the preparation procedure[1] described in the following Paragraphs (*a*) to (*e*) shall be used:

(*a*) All ingredients shall be weighed with accuracy within 0.25 per cent of the weight specified. The final weight of the mixed batch and the sum of the weights of each ingredient shall not differ by an amount exceeding 0.6 per cent for a compounded batch or 0.3 per cent for pure gum or master batched stocks.

(*b*) Mixing of the rubber compound shall be done on a laboratory rubber mill with rolls 12 in. in width by 6 in. in outside diameter having a working distance between the guides of $10\frac{1}{2}$ in. The speed of the slow roll shall be 24 r.p.m. and the gear ratio 1.4, or as near that figure as is compatible with good engineering practice. Sufficient cooling water shall be circulated through the mill rolls to maintain a roll temperature of approximately 158 F. (70 C.).

(*c*) The rubber portion of the batch shall be broken down on a warm mill with mill opening of 0.055 in. until it runs smooth. The mill then shall be adjusted to the required opening in conformity with the following table:

Volume of Batch	Distance Between Ro
1200 cc	0.170 in.
1100 cc	0.160 in
1000 cc	0.145 in.
900 cc	0.130 in.
800 cc	0.120 in.
700 cc	0.110 in.
600 cc	0.100 in.
500 cc	0.085 in.
400 cc	0.070 in.
300 cc	0.055 in.

The compounding ingredients shall be next added to the rubber as rapidly as possible in the following order:

(1) Accelerators and anti-oxidants
(2) Carbon Black
(3) Fillers
(4) Softeners
(5) Sulfur

After the ingredients are all incorporated, the batch shall be cut six times alternating first from one side and then the other. This is to be interpreted as cutting two-thirds of the way across the roll and holding the rubber until the bank just disappears. After the six cuts are completed, the batch shall be cut across and rolled six times with the roll inserted endwise each time until the last when it shall be placed in the rolls lengthwise. Then, as soon as the bank is well balanced, the mill setting shall be adjusted to give a sheet approximately 0.085 in. in thickness, after cooling and the batch is cut from the rolls.

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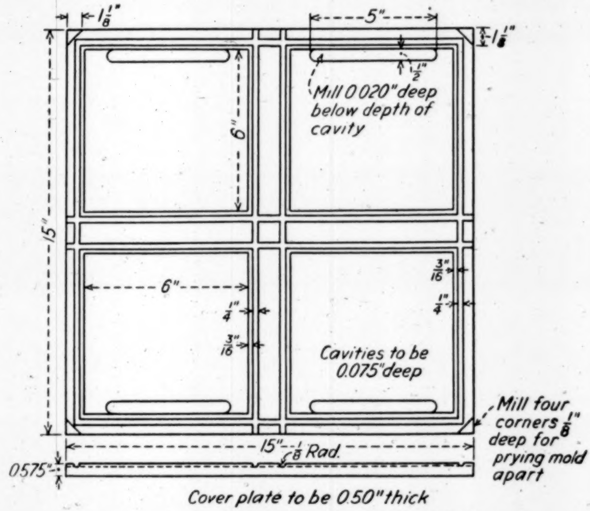
[1] This procedure is substantially in agreement with that of the Physical Testing Committee, Division of Rubber Chemistry, Am. Chemical Soc.

(*d*) The batch shall be cooled to room temperature on a flat surface and cut into slabs $\frac{1}{8}$ in. less in width and length than the corresponding dimensions of the mold cavity. Direction of grain of the rubber shall be marked on each slab. The unvulcanized stock shall be aged 18 to 24 hr. before cure.

NOTE.—It is desirable when possible that the aging be in subdued light in air having a relative humidity of 45 per cent at 82 F. (28 C.).

(*e*) The test slabs shall be vulcanized in a mold similar to that shown in Fig. 1, by being heated at a specified temperature for a given time while held under molding pressure. For this purpose a hydraulic press with heated platens is convenient. The press shall give an intensity of pressure on the mold of not less than 500 lb. per sq. in. The platens shall be of such dimensions that no portion of the slab while curing is nearer than 3 in. to the edge of the platen. In order to avoid cool spots in the platens due to condensed moisture, presses of the bored platen type are recommended. If platens of the chamber type are used, particular attention must be paid to insuring good drainage by placing the steam outlet slightly below the steam chamber. In either case, the actual platen temperatures shall be verified by means of thermocouples in the mold or other suitable temperature measuring device. The time of cure shall be that between the moment the hydraulic pressure reaches its maximum and the moment of release of the hydraulic pressure. The mold shall be brought to the curing temperature before inserting the uncured stock by being placed in


1 1/8"
5"
1 1/8"
1/2"
Mill 0.020" deep below depth of cavity
6"
15"
6"
1/4"
3/16"
3/16"
1/4"
Cavities to be 0.075" deep
Mill four corners 1/8" deep for prying mold apart
15"
1/8 Rad.
0.575"

Cover plate to be 0.50" thick

FIG. 1.—Design for Four Cavity Mold.

the closed press for a period of not less than 20 min. The minimum possible time shall elapse after the stock is placed in the hot mold until the full hydraulic pressure is applied. The slabs shall be removed from the mold immediately after the conclusion of the cure and cooled in water for 10 min. after which they shall be wiped dry and held for test.

Age of Samples

5. All tests of rubber shall be made using specimens which have aged at least 24 hr. after vulcanization. Tests of rubber made more than 60 days after vulcanization shall not be considered as evaluating the original qualities of the material.

NOTE.—Finished rubber products are not in a completely stable condition as regards physical properties. Immediately after cure, the rate of change is rapid. During the first 12 to 24 hr. the rate becomes progressively less until a minimum is reached. Very slow change continues, however, throughout the useful life of the article and is accelerated when the rubber is exposed to heat, light and air.

Condition of Samples

6. Samples and specimens for test shall not be heated, immersed in water nor subjected to any mechanical or chemical treatment prior to test except as specifically prescribed herein or in the standard test method. Any such treatment may definitely change the results of test. Particular attention is necessary to avoid previous stretching through inadvertent handling.

Temperature of Test

7. All tests of rubber shall be made at a room temperature between 70 and 90 F. (21 and 32 C.). Test specimens shall be conditioned at the test temperature for at least 30 min. just prior to test. The actual test temperature shall be recorded in all cases. Close comparisons should not be made between test results obtained under temperature conditions differing by more than 10 F. (5.5 C.).

Separation of Rubber

8. When the tests to be made require prior separation of rubber from cotton fabric or other material, the separation shall be performed without the use of gasoline, if possible, and without rupture or excessive stretching. If necessary to use gasoline, it shall be of a grade which distills below 302 F. (150 C.) and which, upon evaporation, does not leave an appreciable amount of oily residue. To avoid unnecessary stretching, it is desirable to cut the material into strips slightly wider than a test specimen. The separation shall be made gradually and a little at a time while the rubber is gripped near the point of separation. After use of gasoline, the rubber shall be placed so as to permit free evaporation from all parts of its surface and shall be allowed to rest at least 1 hr. before being tested.

Buffing

9. Samples of rubber shall not be buffed, except when necessary, to remove unevenness of surface such as fabric impressions or corrugations which would interfere with an accurate measurement of thickness or when necessary to reduce the thickness to the amount prescribed for test specimens in specific test methods. If required, buffing shall be done by means of a suitable grinding machine and without causing excessive heating of the rubber. It is recommended that a grinder similar to that shown in Fig. 2 be used. The grinder shall have an abrasive wheel of about No. 30 grit, 5 in. in diameter revolving at a speed of 2500 to 3500 r.p.m., and shall be provided with a slow feed in order that very little rubber may be removed at one cut avoiding overheating. When removing fabric impressions or other unevenness, buffing shall not be carried beyond the point at which the unevenness in gage just disappears. When necessary to reduce the thickness of the sample for preparation of test specimens, it may be desirable to slice the rubber nearly to the required thickness and finish by buffing. In any case, the final buffed surfaces shall be finished as smoothly as possible. At least 30 min. shall elapse between the buffing and testing of the specimens.

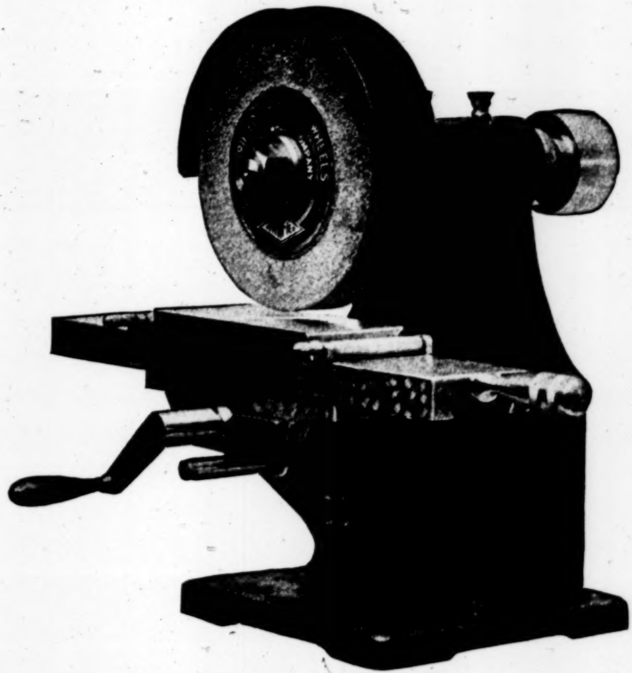


FIG. 2.—Grinder for Buffing Samples.

NOTE.—Specimens with buffed surfaces instead of mold finish usually give slightly lower tensile strength test results because of the tendency for surface roughness to favor premature breaking of the specimens.

Test Methods

10. All tests of rubber parts shall be carried out in accordance with the requirements of the A.S.T.M. standard specification for the material or the A.S.T.M. standard test method for determining the specific physical property required.

Retests

11. Any lot represented by a sample which fails in one or more tests may be retested. For this purpose two additional samples shall be selected. Failure of either in any respect shall be cause for rejection.

TENTATIVE METHODS OF TENSION TESTING OF VULCANIZED RUBBER[1]

A.S.T.M. Designation: D 412 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These methods include standard procedures for determining stress-strain properties, tensile strength, ultimate elongation and permanent set of the usual grades of soft vulcanized rubber such as tire carcass and tread compounds or those used in most mechanical rubber goods. They do not apply to the testing of material ordinarily classed as hard rubber.

(*b*) Except as may be otherwise specified in these methods, the requirements of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (A.S.T.M. Designation: D 15 - 35 T) of the American Society for Testing Materials[2] shall be complied with and are made a part of these methods.

Description of Terms

2. (*a*) *Tensile Strength* is the tension load per unit cross-sectional area required to break a test specimen of the type and in the manner herein described.

NOTE.—Since rubber when so stressed usually stretches to a high degree with accompanying substantial reduction in cross-sectional area, and since precise measurement of the dimensions at the moment of breaking is not possible, the calculation of intensity of load is referred in all cases to the original cross-section.

(*b*) *Elongation* is the extension produced by a tension load in a section of a test specimen between gage marks placed on it, and is expressed as a percentage of the original distance between the marks. Ultimate elongation is the elongation at the moment of rupture. Elongation is also correctly designated by the term "strain."

Tensile Stress is the intensity of load referred to the original cross-section at the corresponding stated percentage of elongation which it produces. It is expressed in pounds of tension load per square inch at the particular elongation, for example, 1000 lb. per sq. in. at 500 per cent elongation, and is often designated by the term "modulus." It is used as an index of stiffness.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] See p. 1153.

Permanent Set refers to the extension remaining after a test specimen has been stretched and held at a specified elongation for a given period of time, relieved of load and allowed to recover during a specified interval of rest as herein described. It is expressed as a percentage of the original length and is used as an index of elasticity.

TENSION TESTING APPARATUS

Type

3. Tensile strength, elongation and stress-strain tests shall be made on a power-driven apparatus, preferably of the inclination-balance or pendulum type. A spring-balance type of apparatus may be used if provided with a device which will indicate the actual maximum load at which rupture took place and if provision is made to prevent recoil of the spring.

Requirements

4. The machine shall fulfill the following requirements:

(*a*) The applied tension as indicated by a dial or scale shall be accurate within ± 1 per cent.

(*b*) The indicator shall remain at the point of maximum load after rupture of the test specimen.

(*c*) The grips which hold the specimen in the testing machine shall be of a type which tightens automatically and exerts a uniform pressure across the gripping surface proportional to the applied tension so as to avoid uneven slipping and to insure failure of the test specimen in its constricted portion.

(*d*) The rate of travel of the power actuated grip shall be 20 in. per min. and shall be uniform at all times.

(*e*) Provision shall be made for measuring the elongation by a scale graduated to 0.1 in. and suitably attached to measuring trammel points or held back of the test specimen.

Capacity

5. The testing machine used for a given test specimen shall be of such capacity that the maximum load required to break the specimen shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity. For tests of most rubber compounds using one of the test specimens herein described a machine of 150-lb. maximum capacity will be satisfactory. For general use in tension testing of rubber, possible separation of the grips of at least 30 in. shall be provided.

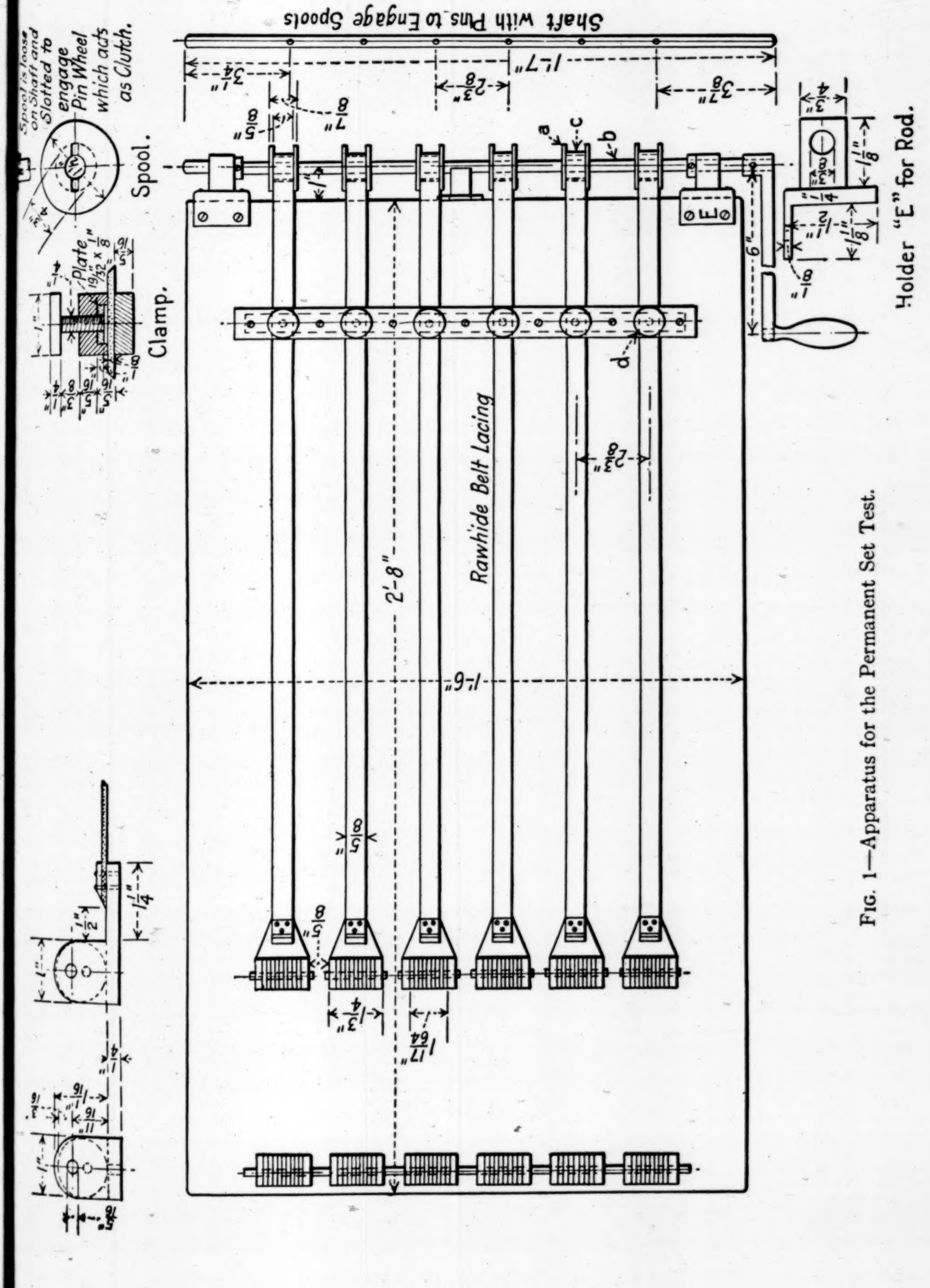
Shaft with Pins to Engage Spools
1'-7"
3/4"
2 3/8"
3 7/8"
5/8"
7/8"
1/4"
a
b
c
d
E
6"
1/8"
1 1/8"
3/4"
1/4"
Holder "E" for Rod.
Spool is loose on Shaft and Slotted to engage Pin Wheel which acts as Clutch.
Spool.
Plate 19/32" x 1/8"
Clamp.
1"
5/16"
3/4"
Rawhide Belt Lacing
2'-8"
1'-6"
2 3/8"
5/8"
1 3/4"
1 17/64"
1 1/4"
1/2"
1"
11/16"
3/16"

Fig. 1—Apparatus for the Permanent Set Test.

Set Test Apparatus

6. Permanent set tests may be carried out on the power driven tension machine described or the special apparatus illustrated in Fig. 1 may be employed.

TEST SPECIMENS

Dies

7. Unless otherwise prescribed in the specifications for the material being tested, the specimens for tension tests shall be stamped out with a steel die constructed substantially in accordance with Fig. 2. The dies shall be kept sharp and free from nicks to avoid leaving ragged edges on the rubber. Cutting may be facilitated by wetting the rubber surface and the cutting edges of the die. The rubber shall be rested on a smooth, slightly yielding surface which will not injure the blade. Light-weight cardboard or a piece of leather belting is suitable. Care shall be taken that the

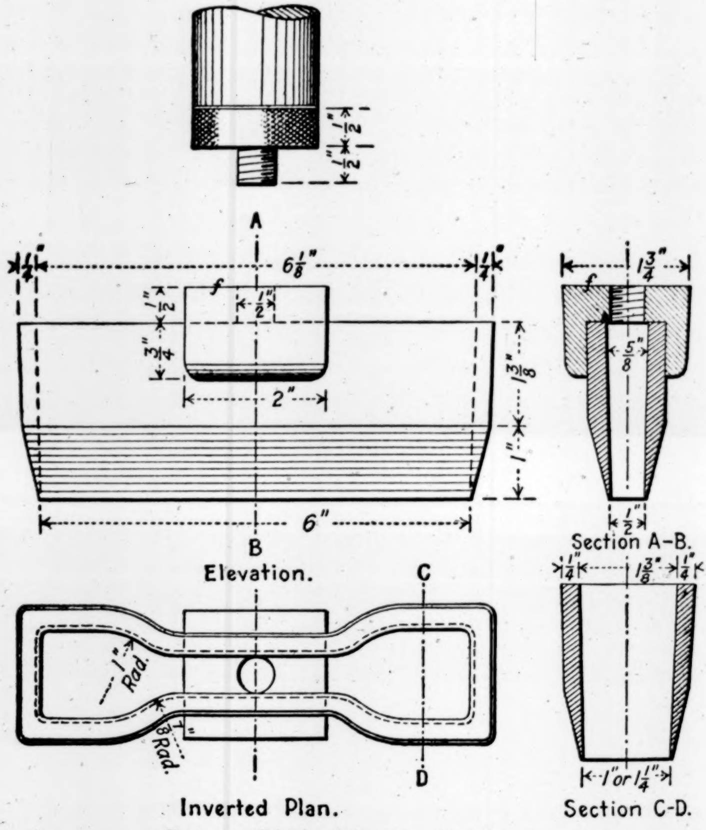
1/2"
1/2"
A
1/4"
6 1/8"
1/4"
f
1/2"
1/2"
3/4"
2"
1 3/8"
1"
6"
B
Elevation.
1 3/4"
f
5/8"
1/2"
Section A-B.
C
1/4"
1 3/8"
1/4"
1" Rad.
1/8" Rad.
D
1" or 1 1/4"
Inverted Plan.
Section C-D.

Fig. 2.—Die for $\frac{1}{2}$ by 2-in. Specimens.

cut edges are perpendicular to the other surfaces of the specimen and have a minimum of concavity.

Shape

8. The specimen stamped out shall conform in shape to Fig. 3 A, B or C, and shall not vary in width in the reduced section by more than ±0.001 in. from the dimension shown. In no case shall the thickness of the test specimen exceed $\frac{1}{8}$ in.

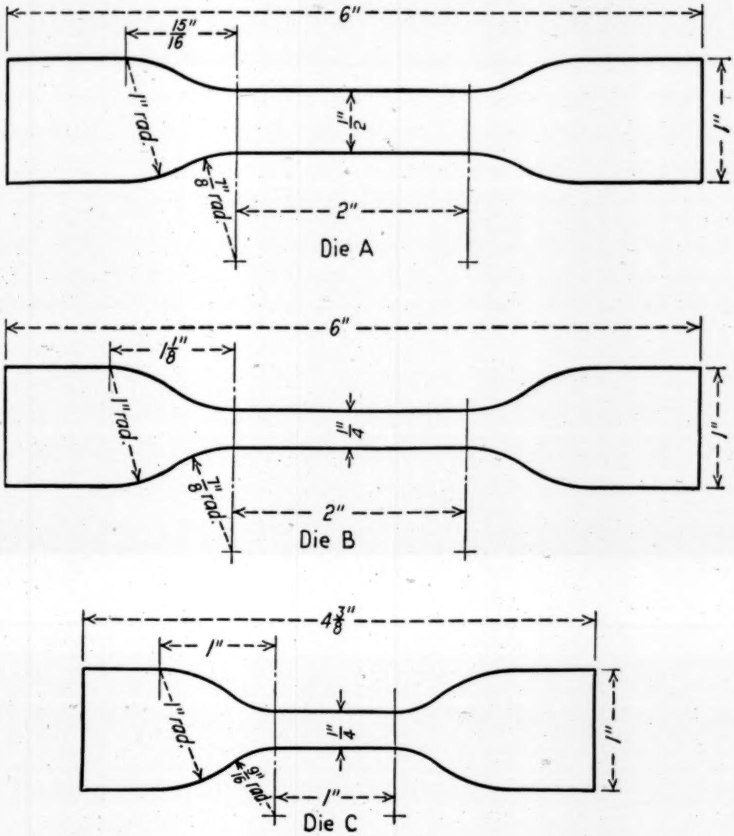

FIG. 3.—Tensile Strength and Elongation Test Specimens.

Die A shall be used when the size of the sample and the tension and stretch limits of the testing machine permit, with exceptions as explained below. If the tension limit is too high for the machine, use Die B. If the stretch is too high for the machine, use Die C. Die C shall also be used for samples which are too small for A or B. In all cases in which the sample and testing machine limitations permit a choice in die shapes, the die giving the highest test values shall be used, as such higher results will be nearer to the true value of the material.

Gage Marks

9. Two parallel gage lines for use in determining elongation shall be marked on the reduced section perpendicular to the longitudinal axis of the specimen one on each side of the center and $\frac{1}{2}$ in. or 1 in. therefrom, as

required. The marks shall be as narrow as possible consistent with legibility. Use of a stamp with parallel steel blades is recommended but care shall be taken not to injure the rubber.

Measurement of Thickness

10. (*a*) The thickness shall be measured with a micrometer graduated to 0.001 in. having a presser foot 0.25 in. ±0.01 in. in diameter exerting a total force of 9.0 oz. ±0.1 oz. The load shall be applied by means of a weight.

(*b*) The minimum thickness and width between the gage marks shall be taken in calculating the area to be used in determining the tensile strength of the specimen.

Number of Test Specimens

11. (*a*) Three specimens per sample shall be tested for determinations of tensile strength, elongation, and stress-strain properties. Results on specimens which break outside of the straight reduced section or which are found to be imperfect shall be discarded and retests shall be made. In case the ultimate tensile strengths fail to check within 5 per cent of the highest value obtained, additional specimens shall be tested until two or more such check results are obtained. The final values shall be the averages of the check tests discarding the determinations on samples which are outside of the above limit.

(*b*) Two specimens per sample shall be tested for permanent set and the results shall not differ by more than 25 per cent of the percentage values obtained. In case of greater variation than specified, additional specimens shall be tested. The final value shall be the average of the check tests. Results on specimens found to be imperfect shall be discarded and retests shall be made.

PROCEDURE

12. (*a*) *Tensile Strength and Ultimate Elongation.*—The test specimen shall be placed in the grips using care to adjust them symmetrically in order that the tension shall be distributed uniformly over the cross-section. The grips shall be separated at the specified rate of speed until rupture takes place and during separation, the distance between the gage marks on the specimen shall be noted continuously so that at the instant of rupture the distance is known within 0.1 in. This value shall be recorded together with the original distance between the gage marks from which data the ultimate elongation may be calculated. After rupture of the specimen, the breaking load in pounds shall be noted from the dial or scale and recorded together with the original minimum width and thickness of the specimen so that the tensile strength may be calculated.

(*b*) *Stress-Strain Properties.*—The procedure shall be the same as in Paragraph (*a*) except that the load and extension shall be recorded at equal increments of 100 per cent elongation as well as at rupture. Use of an autographic or spark recorder for registering observed loads is recommended. A tension testing machine equipped with a dynamometer head of the compensating type is convenient in eliminating calculations and its use is permitted in stress-strain tests.

(*c*) *Permanent Set.*—The test specimen shall be placed in the grips of the test apparatus as in Paragraph (*a*) and the grips separated at the machine speed or by hand at a uniform rate of speed such as to require approximately 15 sec. to reach the specified elongation. The specimen shall be held in this stretched position for 10 min., released immediately but without being allowed to snap back and allowed to rest for 10 min. The distance between the gage marks shall then be measured to the nearest 0.01 in. and recorded together with the original distance between the marks. The difference is the measure of the permanent set. If no specified elongation is given for the permanent set determination, the test specimen shall be stretched an amount equal to three-fourths of the ultimate elongation determined as in Paragraph (*a*).

REPORT

Calculation of Results

13. (*a*) *Tensile Strength* shall be calculated by dividing the breaking load in pounds by the original area of the cross-section of the test specimen in square inches and shall be expressed in pounds per square inch.

(*b*) *Ultimate elongation* shall be calculated by subtracting the original distance between gage marks in inches from the total distance between the marks at the time of rupture as measured in Section 12 (*a*) and expressing this difference as a percentage of the original distance, as follows:

$$\text{Ultimate Elongation, per cent} = \frac{(\text{Distance at Break} - \text{Original Distance})}{\text{Original Distance}} \times 100$$

(*c*) *Stress-Strain Properties.*—Tensile stresses shall be calculated as in the case of tensile strength except that the observed loads shall be used in place of the breaking load. Elongation or strain shall be calculated as in the case of ultimate elongation except that the observed distance between the gage marks at each recorded extension shall be used in place of the distance at break.

(*d*) *Permanent Set* shall be calculated as a percentage of the original distance between the gage marks by taking the difference between the gage mark distance after the rest period and the original distance as described in Section 12 (*c*), multiplying by 100 and dividing the product by the original distance.

Report

14. The report shall include the following:

(*a*) The results calculated in accordance with Section 13.

(*b*) All observed and recorded data on which the calculations are based.

(*c*) The date of vulcanization of the rubber, if known.

(*d*) The date of test.

(*e*) The temperature of the test room.

(*f*) The type of test machine used.

(*g*) The dimensions of the die used in preparing the test specimens.

TENTATIVE METHODS OF TEST
FOR
ACCELERATED AGING OF VULCANIZED RUBBER[1]

A.S.T.M. Designation: D 428 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. (*a*) These methods are intended for use in estimating the relative resistance of vulcanized rubber compounds to age deterioration. No direct correlation between these accelerated tests and natural life of rubber is given nor implied. Since the rate at which deterioration proceeds during the normal life of rubber varies widely depending on conditions of exposure to heat, light and air and on the composition and state of cure of the rubber, these accelerated tests are comparative only and must be evaluated against the performance of rubber compounds of which both the natural and accelerated aging characteristics are known.

(*b*) Except as otherwise specified in these methods, the requirements of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (A.S.T.M. Designation: D 15 - 35 T) of the American Society for Testing Materials[3] shall be complied with and are made a part of these methods.

(*c*) In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular material, the latter shall take precedence.

Types of Tests

2. (*a*) Aging tests of rubber consist of subjecting test specimens having previously determined physical properties to controlled deteriorating influences for known periods after which the physical properties are again measured and the changes noted. In these methods, two types of test are given which differ in that the specimens are exposed at an elevated temperature to different conditions of oxidizing atmospheres. Neither type

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Accepted for publication as tentative by Committee E-10 on Standards, September 28, 1935.

[3] See p. 1153.

includes exposure to light. They are designated as (*1*) air-oven aging test, and (*2*) oxygen-pressure-chamber aging test.

(*b*) In both types of aging tests, the physical properties used to measure the deterioration of the rubber in addition to visual and manual inspection, are tensile strength, ultimate elongation and stress-strain relationship. Except as otherwise specified in these methods, the determination of these properties before and after aging shall be carried out in accordance with the Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 – 35 T) of the American Society for Testing Materials.[1]

Air Oven

3. The air oven shall conform to the following requirements:

(*a*) The interior size shall be as follows or of an equivalent volume:

Interior size of air oven	Minimum	12 by 12 by 12 in.
	Maximum	36 by 36 by 48 in.

(*b*) Provision shall be made for suspending specimens vertically without touching each other or the sides of the aging chamber.

(*c*) The operating temperature shall be 70 C. ± 1 C.

(*d*) The temperature variation in various parts of the oven shall not exceed 2 C.

(*e*) The heating medium for the aging chamber shall be air circulated within it at atmospheric pressure.

(*f*) The source of heat is optional but shall be located in the air supply outside of the aging chamber proper.

(*g*) A recording thermometer located in the upper central portion of the chamber near the center of the aging specimens shall be provided to record the actual aging temperature.

(*h*) Automatic temperature control by means of thermostatic regulation shall be used.

(*i*) The following special precautions shall be taken in order that accurate, uniform heating is obtained in all parts of the aging chamber:

(*1*) The heated air shall be thoroughly circulated in the oven by means of mechanical agitation. When a motor-driven fan is used, the air must not come in contact with the fan motor brush discharge because of danger of ozone formation.

(*2*) Baffles shall be used as required to prevent local overheating and dead spots.

(*3*) The thermostatic control device shall be so located as to give accurate temperature control of the heating medium. The preferred location is adjacent to the recording thermometer.

(*4*) An actual check shall be made by means of maximum reading thermometers placed in various parts of the oven to verify the uniformity of the heating.

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[1] See p. 1159.

Oxygen Pressure Chamber Equipment

4. The oxygen pressure chamber shall consist of a metal vessel designed to retain an internal atmosphere of oxygen gas under pressure with provisions for placing rubber specimens within it and subjecting the whole to controlled uniform temperature. Two suggested designs which are suitable are shown in Figs. 1 and 2. The equipment shall conform to the following requirements:

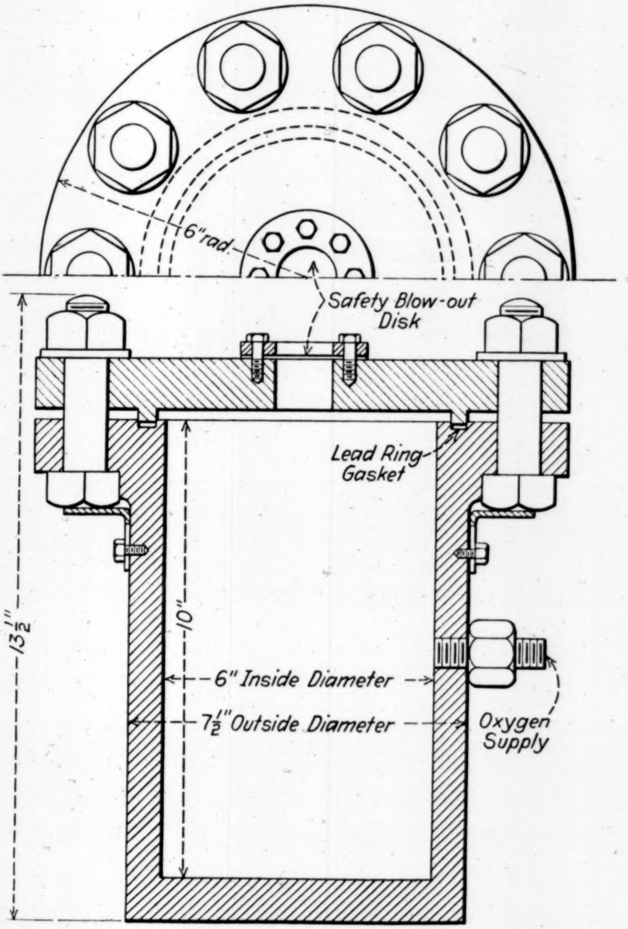
6" rad.
Safety Blow-out Disk
Lead Ring Gasket
13½"
10"
6" Inside Diameter
7½" Outside Diameter
Oxygen Supply

FIG. 1.—Oxygen Pressure Aging Chamber, Non-Jacketed for Water or Air Bath.

(*a*) The size of the chamber shall be optional but shall be such that the specimens may be suspended therein vertically without undue crowding and without touching each other or the sides of the chamber.

(*b*) The operating temperature shall be 70 C. ± 1 C. determined by measuring the temperature of the heating medium which shall be considered the same as that of the pressure chamber.

(*c*) The source of heat is optional but necessarily must be located outside of the aging chamber proper.

(*d*) The heating medium is optional but water is preferred because of more rapid heat transfer. When the design shown in Fig. 1 is used, it is convenient to employ for the heating a calorimeter water bath in which the entire chamber is immersed. If air is used, precautions similar to those specified in Section 3 (*i*) for the air oven must be observed to insure uniform heating.

(*e*) Automatic temperature control of the heating medium by means of thermostatic regulation shall be used.

(*f*) A recording thermometer located in the heating medium shall be provided to record the actual temperature. Preferably, the thermometer bulb should be close to the wall of the pressure chamber but not touching it.

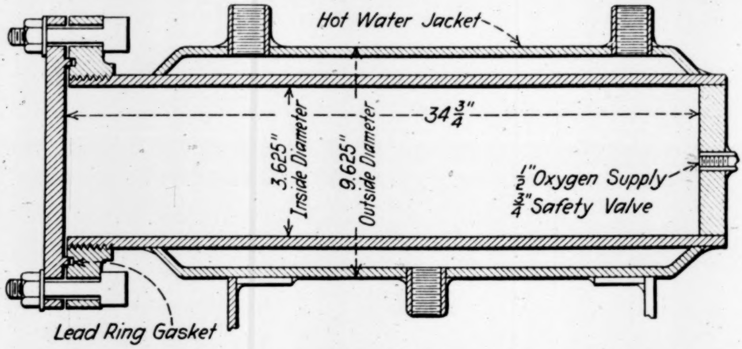

FIG. 2.—Oxygen Pressure Aging Chamber, Hot-Water Jacketed.

(*g*) Positive, rapid and complete circulation of the heating medium shall be maintained so as to assure accurate, uniform heating.

(*h*) The pressure of oxygen supplied to the aging chamber shall be 300 ± 10 lb. per sq. in. as measured by a calibrated pressure gage.

(*i*) The pressure chamber shall be equipped with a reliable safety valve set for release at 500 lb. per sq. in. pressure.

NOTE: *Caution.*—Adequate safety provisions are important when heating oxidizable organic materials in oxygen since the rate of reaction may become very rapid in some cases, particularly if large surface area is exposed, and very high pressures may be developed.

Shape of Test Specimens

5. Dumb-bell shaped test specimens, prepared as described in the Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 – 35 T) of the American Society for Testing Materials[1] shall be considered standard. Their form shall be such that no mechanical, chemical or heat treatment will be required after aging. If buffing is necessary, it shall be performed prior to the aging cycle.

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[1] See p. 1159.

Size of Test Specimens

6. The dimensions of the test specimens for calculating the physical properties shall be measured prior to starting the aging cycle. Care shall be taken that the material used for marking the gage lines on the specimens is not detrimental to the rubber during aging exposure causing the specimens to break at the marks prematurely during test. Only specimens of similar dimensions having approximately the same exposed areas may be compared with each other.

Number of Test Specimens

7. At least three specimens shall be used to determine the average original physical properties of the rubber and also three or more specimens of the same material for each aging interval of the test.

Tests of Unaged Specimens

8. The stress-strain properties including tensile strength and ultimate elongation of the original unaged specimens shall be determined within 24 hr. of the start of the aging period. Results on specimens which break outside of the straight reduced section or which are found to be imperfect shall be discarded. Retests shall be made of original unaged specimens so discarded.

Accelerated Aging of Specimens

9. The specimens for aging shall be placed in the aging chamber after it has been preheated to the operating temperature. It is recommended that not more than 2.0 g. of actual rubber or oxidizable substance per cubic inch of capacity be placed in the chamber. Simultaneous aging of a mixed group of different compounds shall be avoided if possible. For instance, high-sulfur compounds should not be aged with low-sulfur compounds and those containing anti-oxidants should not be aged with those having no age-resistors. Some migration is known to occur. When starting an oxygen-pressure aging test, the air shall be flushed out by releasing the oxygen pressure and refilling and the chamber shall be checked to make certain the apparatus does not leak.

(*b*) The aging interval shall start at the time the specimens are placed in the heated chamber and shall continue for a measured time interval. The selection of suitable intervals of aging will depend on the rate of deterioration of the particular material being tested. Air-oven tests are commonly extended over intervals of days and oxygen-pressure-chamber tests for periods of hours. Intervals frequently used are as follows:

Air-oven tests	2, 4, 7 and 14 days
Oxygen-pressure-chamber tests	24, 48, 72 and 96 hr.

(*c*) Such aging intervals shall be used that the deterioration will not be so great as to prevent determination of the final physical properties.

In experimental work, it is desirable to use a range of periods, while for routine tests of known materials fewer intervals may be employed.

(*d*) At the termination of the aging interval, the specimens shall be removed from the aging chamber, cooled to room temperature on a flat surface and allowed to rest not less than 16 hr. nor more than 48 hr. before determination of the physical properties. In relieving the pressure from the oxygen pressure chamber preparatory to removing the aged specimens, it is essential that the release be slow and uniform, requiring at least 2 min. so as to avoid possible formation of porosity in the specimen.

Tests of Aged Specimens

10. The tensile strength, ultimate elongation and, if possible, stress-strain properties of the specimens aged for different intervals shall be determined as the intervals terminate in the progress of the aging disregarding the fact that more specimens may still be aging. In determining the physical properties after aging, the final values shall be the average of results from at least two specimens including that one giving the highest value for ultimate tensile strength and any which check that value within 10 per cent. Results of tests of all other specimens shall be discarded. In the event that discarding of aged specimens both from faulty breaks and failure to check does not leave two satisfactory determinations, additional specimens shall be aged and tested until two or more check results from properly broken specimens are obtained. After completion of the tests, the broken, aged specimens shall be examined visually and manually and their condition noted.

Expression of Results

11. The results of the aging test shall be expressed in the form of percentage of deterioration in each physical property (tensile strength, ultimate elongation or tensile stress), calculated as follows:

$$\text{Percentage of Deterioration} = \frac{(\text{Original Value} - \text{Value after Aging}) \times 100}{\text{Original Value}}$$

Report

12. The report shall include the following:

(*a*) The results calculated in accordance with Section 11.

(*b*) All observed and recorded data on which the calculations are based.

(*c*) Type of aging test.

(*d*) The aging interval.

(*e*) The duration, temperature and date of vulcanization of the rubber, if known.

(*f*) Dates of original and final determinations of physical properties.

(*g*) Dimensions of test specimens.

TENTATIVE METHODS OF TEST

FOR

ADHESION OF VULCANIZED RUBBER (FRICTION TEST)[1]

A.S.T.M. Designation: D 413 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) These methods of test are intended to be used for measuring the strength of adhesion between plies of fabric bonded with rubber or the adhesion of the rubber layer in articles made from rubber attached to another material. They are applicable only when the adhered surfaces are approximately plane or uniformly circular as in belting, hose, tire carcasses, or rubber-covered sheet metal. When the adhered surfaces contain sharp bends, angles or other gross irregularities which cannot be avoided in preparing test specimens, special methods must be employed for evaluating adhesion.

(*b*) Two general methods of test are given. The first involves application of force by means of weights and is called the "Dead-Weight Method." The second employs a tension testing machine and is known as the "Machine Method."

(*c*) As covered by these methods, an adhesion test shall be understood to consist of applying to a test specimen under specified conditions, a measured force sufficient to strip from the specimen at a measured rate a layer of moderate thickness with separation at the adhered surfaces. The numerical value of the adhesion may therefore be expressed as (*1*) average force required to cause separation at a definite rate, or (*2*) average rate of separation caused by a known or specified force. In the machine method, the rate of separation is fixed and the adhesion value must be expressed in terms of the measured tension. With the dead-weight test, either method can be used but the latter is preferable and will be here employed.

(*d*) Except as may be otherwise specified in these methods, the requirements of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (A.S.T.M. Designation: D 15 – 35 T) of the

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

American Society for Testing Materials[1] shall be complied with and are made a part of these methods.

(*e*) In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular material, the latter shall take precedence.

TEST SPECIMENS

Size and Shape

2. (*a*) Test specimens shall conform to one of two types as follows:

Strip Specimens.—Plane strips having a width of 1.00 in. ± 0.01 in., and a minimum length such as to permit separation over sufficient distance to indicate the adhesion value.

Ring Specimens.—Closed rings having a width of 1.00 in. ± 0.01 in. and maximum internal diameter of 4 in. Ring specimens shall be tested only by the dead-weight method.

(*b*) Test specimens may vary in thickness according to the construction of the article being tested but the portion from which a ply or layer is being separated shall not be of less thickness than such ply or layer and in no case shall the thickness of the latter exceed $\frac{1}{4}$ in. If necessary, in order to comply with this requirement, slicing or buffing may be employed.

(*c*) Curved specimens for test in strip form shall have curvature only in the length dimension of the test specimen.

Cutting of Specimens

3. (*a*) If practicable, the test specimens shall be cut from the article to be tested in such manner that the adhered parts shall have the same one-inch width. When necessary or when so specified, only the layer which is to be separated by application of load may be cut to the one-inch width but in such case, the portions of that layer remaining outside of the test width shall be removed from the other layers to avoid edge constriction during separation.

(*b*) Cutting of test specimens shall be done using a sharp tool which will leave clean edges. Ring specimens as from hose samples are conveniently prepared by mounting the material on a smooth, close-fitting, slightly tapered wooden mandrel which can be rotated in a lathe and cutting 1-in. sections with a sharp-pointed wet knife forced gradually through the material.

(*c*) Rings having internal diameters over 4 in. shall be cut through and opened to form strip specimens.

DEAD-WEIGHT METHOD

Apparatus

4. The apparatus required for the adhesion test by the dead-weight method consists of a supporting frame, testing clamps, mandrels, calibrated

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[1] See p. 1153.

weights and weight carriers. The supporting frame shall be of such design that clamps for strip specimens may be hung on it vertically and that mandrels for strip specimens may be supported on it horizontally. The frame must have sufficient height to permit weights to be suspended from the test specimens by means of clamps and to hang freely during the progress of the test. Provision also shall be made to support the mandrels so that they may revolve freely with minimum friction. Suitable apparatus is shown in Figs. 1 and 2.

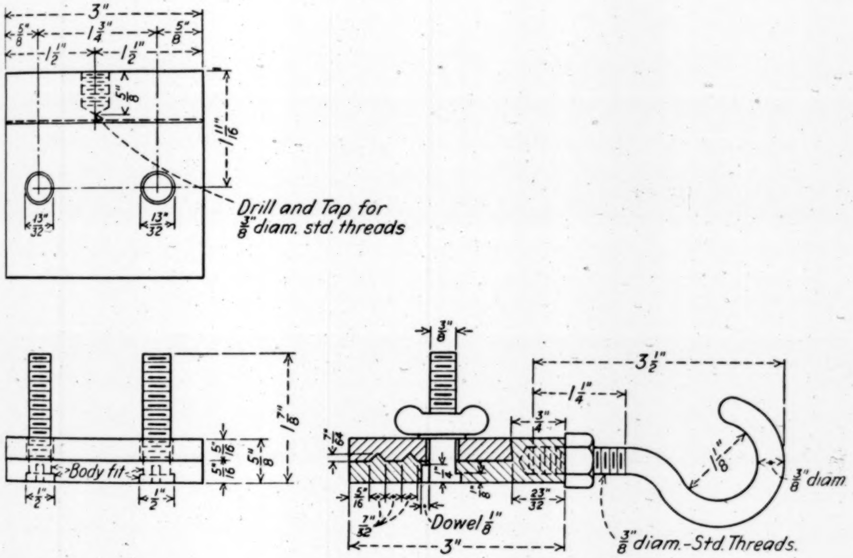
3"
5/8"
1 3/4"
5/8"
1 1/2"
1 1/2"
5/8"
1 11/16"
13/32"
13/32"
Drill and Tap for
3/8" diam. std. threads
Body fit
1/2"
1/2"
5/16"
5/16"
5/8"
1 7/8"
3/8"
7/64"
5/16"
7/32"
1/4"
1/8"
Dowel 1/8"
3/4"
23/32"
3"
3 1/2"
1 1/4"
1 1/8"
3/8" diam
3/8" diam.-Std. Threads.

FIG. 1.—Clamp for Adhesion Test.

Procedure

5. (*a*) *Testing Strip Specimens.*—The parts to be tested shall be separated by hand at one end of the strip specimen a sufficient distance to permit attaching the jaws of the testing clamp. The strip shall be suspended from the supporting frame by the separated end, all separate parts of which except the one under test, shall be held in the jaws of the testing clamp. A minimum weight sufficient to maintain the strip specimen in approximately a vertical position shall be attached to the lower end of the test specimen, or the specimen may be held against a vertical plate in such a manner as to keep the specimen in approximately a vertical position during test. A specified or known weight shall be applied by means of a clamp and weight carrier to the layer of which the adhesion is to be determined. The weight of the clamp and carrier shall be included in the total weight causing separation. Suitable provision shall be made for releasing the weight

slowly without jerking and in such a manner that the separating layer will be stripped from the specimen approximately at an angle of 180 deg.

(*b*) *Testing Ring Specimens.*—The ring specimen shall be placed snugly on a mandrel having an outside diameter substantially the same as the internal diameter of the ring. The parts to be tested shall be separated sufficiently by hand to permit attaching the jaws of the testing clamp. With the mandrel resting on the supporting frame, a known or specified weight shall be applied by means of the clamp and a weight carrier to the layer of which the adhesion is to be tested. The weight of the clamp and carrier shall be included in the total weight causing separation. Suitable provision shall be made for releasing the weight slowly without jerking and in such a manner that the separating layer will be stripped from the specimen approximately at an angle of 90 deg.

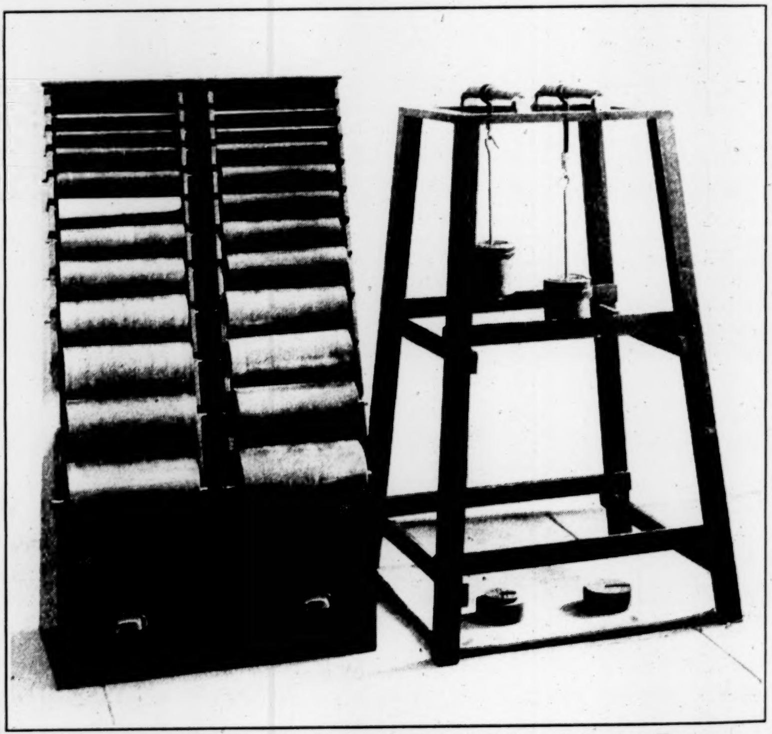

FIG. 2.—Mandrels and Frame for Dead-Weight Adhesion Test

(*c*) *Rate of Separation.*—The rate of separation shall be determined by observing the duration of the test with a stop-watch or a watch having a second hand and by measuring, after the weight has been removed, the length stripped between marks placed at the beginning and end of the test on the other portion than that stripped.

MACHINE METHOD

Specimens

6. Only strip specimens shall be tested for adhesion by the machine method.

Apparatus

7. Adhesion tests by the machine method shall be made on a power-driven apparatus, preferably of the inclination balance or pendulum type, although a spring-balance apparatus may be used. The machine shall fulfill the requirements of the following Paragraphs (*a*) to (*f*):

(*a*) The applied tension as measured and recorded shall be accurate within ± 1 per cent.

(*b*) The grips which hold the specimen in the testing machine shall clamp firmly and prevent slipping at all times during the test.

(*c*) The rate of travel of the power-actuated grip shall be 2 in. per min. uniformly throughout the test giving a rate of separation of 1 in. per min.

(*d*) The machine shall be operated without any device for maintaining maximum load indication. In pendulum type machines, the weight lever shall swing as a free pendulum without engagement of pawls.

(*e*) The machine shall be autographic giving a chart having rate of separation as one axis and applied tension as the other axis of coordinates.

(*f*) The machine shall be of such capacity that the maximum applied tension during adhesion test shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity.

Procedure

8. The parts to be tested shall be separated by hand at one end of the test specimen sufficiently to permit clamping in the grips of the machine. The separated end of the specimen with all separate parts except the one under test securely gripped shall be attached to the recording head by means of a clamp using care to adjust it symmetrically in order that the tension shall be distributed uniformly. Provision shall be made to maintain the strip during test approximately in the plane of the clamps. This may be done either by attaching the minimum weight required to the free end of the specimen or by holding the specimen against a plate attached to the stationary clamp but, in either case, the added weight shall be taken into account in determining the load causing separation. The layer of which the adhesion is to be tested shall be gripped symmetrically and firmly without twisting in the power-actuated clamp. The autographic mechanism and chart shall be adjusted to zero and the machine started. The separating layer shall be stripped from the specimen approximately at an angle of 180 deg. and the separation continued for a sufficient distance to indicate the adhesion value.

PRECAUTIONS AND CHECK TESTS

Tearing

9. If, during a test, one of the parts begins to tear, instead of separating from the other part of the specimen, the material being torn shall be cut with a knife up to the surface of contact between the two parts and the test started again. If one of the parts repeatedly tears, instead of separating from the other part, a satisfactory result may be secured in the dead-weight method by reducing the amount of the weight used if this is permitted. In case of repeated tearing when using the machine method, the average load at which tearing occurs shall be taken as the result of the test. In cases of tearing, the results shall be so designated.

Effect of Temperature

10. The results of this test are affected by temperature. Elevating the temperature causes a faster rate of stripping under a given load. The temperature during test shall therefore be between 70 and 90 F. (21 and 32 C.) and the actual temperature shall be recorded.

Interpretation of Results

11. (*a*) In the dead-weight method, no stripping is started unless a certain weight is used. Small increments in weight do not progressively cause proportional increases in rate of separation. With increasing weight the rate increases slowly at first and finally very rapidly. Rate of separation must therefore be interpreted carefully. A specimen required to separate not more than 1 in. per min. under 20-lb. weight might be regarded as very inferior if the test result was 5 in. per min. The same specimen might not strip at all under 15-lb. weight and might meet the requirement with 18-lb. weight.

(*b*) The true adhesion value is not determined in case the specimens repeatedly tear. The test, however, indicates that the strength of adhesion exceeds the strength of the material and that the adhesion value is not less than the result obtained.

(*c*) Adhesion values may differ between different plies of the same article of plied construction and also at different points along the same ply. The adhesion value of one ply to another is taken as the average result of the test over a reasonable distance of separation. When possible, a distance of separation of at least 4 in. shall be used.

Check Tests

12. The adhesion value shall be based on the result of a single test. In case of testing to meet a specified value, one check test shall be made if the average strength as determined by the machine method fails by less than one-half pound to meet the specifications or if the rate of separation determined by the dead-weight method exceeds the specified rate by not more than ten per cent. The check test result shall be considered final.

REPORT

Expression of Results

13. (*a*) With the dead-weight method, the value of the adhesion shall be reported as inches of separation per minute per inch of width under a stated weight.

(*b*) With the machine method, the autographic chart constitutes the report but the value of the adhesion shall be determined by drawing on the chart the best average line between the maximum and minimum load values. The load so indicated expressed in pounds per inch width for separation at 1 in. per min. shall be reported as the adhesion value.

Report

14. The report shall include the following:

- (*a*) Results of the adhesion test determined in accordance with Section 13.
- (*b*) All observations and recorded data on which the results are based.
- (*c*) The date of manufacture or vulcanization of rubber, if known.
- (*d*) The date of test.
- (*e*) Statement of method used.
- (*f*) Temperature of test room.
- (*g*) Dimensions of test specimen.

TENTATIVE METHOD OF TEST

FOR

ADHESION OF VULCANIZED RUBBER TO METAL[1]

A.S.T.M. Designation: D 429 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. (*a*) This method is intended to be used for testing the strength of adhesion of rubber to metal in articles where a rubber part is assembled between two parallel metal plates.

(*b*) The method is designed primarily to apply to specimens prepared in a laboratory under standardized conditions such as may be used to provide data for development and control of rubber compounds and methods of manufacture. With slight modifications as indicated, it may also be used for obtaining comparative adhesion tests of production parts whenever the design permits preparation of suitable test specimens. It is applicable in the case of many automotive parts in which rubber is used for the purpose of damping vibration.

(*c*) The method does not cover the testing of adhesion of rubber to metal when the part has metal on one side of the rubber only. For such cases reference should be made to the Tentative Methods of Test for Adhesion of Vulcanized Rubber (Friction Test) (A.S.T.M. Designation: D 413 - 35 T) of the American Society for Testing Materials.[3]

(*d*) Except as otherwise specified in this method, the requirements of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (A.S.T.M. Designation: D 15 - 35 T) of the American Society of Testing Materials[4] shall be complied with and are made a part of this method.

Testing Machine

2. A tension testing machine conforming to the requirements of the Tentative Methods of Verification of Testing Machines (A.S.T.M. Desig-

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Accepted for publication as tentative by Committee E-10 on Standards, September 28, 1935.

[3] See p. 1173.

[4] See p. 1153.

nation: E 4 – 35 T) of the American Society for Testing Materials[1] shall be used for measuring the strength of adhesion. The moving head of the machine shall travel at the rate of 1 in. per min. The machine shall be provided with a recording device to give the total pull in pounds at the conclusion of the test. A machine of not more than 10,000-lb. capacity will be found suitable in most cases.

Grips

3. The fixtures for holding the specimen in the testing machine will depend on the type of specimen but in all cases shall be provided with ball seats to permit proper centering of the load during test. Specially molded laboratory specimens shall be attached by means of threaded studs on the metal parts as shown in Fig. 1, but with specimens cut from production parts the clamp illustrated in Fig. 4 shall be used.

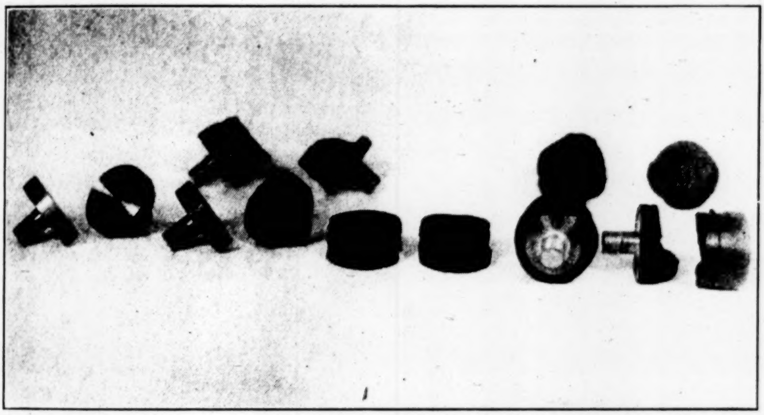

FIG. 1.—Views of Test Specimen Showing Individual Metal Parts and Rubber Cylinders.

Standard Test Specimens

4. The standard test specimen shall consist of a cylinder of rubber 0.500 in. ± 0.005 in. in thickness and 1.579 in. ± 0.001 in. in diameter having its circular ends attached to the faces of two metal plates each 0.375 in. in thickness and of the same diameter as the rubber cylinder. The metal plates shall have smooth flat faces which shall be parallel in the finished specimen. The cylindrical shape is used to eliminate sharp corners and to give uniform distribution of the pulling force. The specified diameter which provides a cross-sectional area of 2 sq. in. and the $\frac{1}{2}$ in. thickness of rubber have been selected to provide as large a volume of rubber as advisable without introducing possibility of variations in cure and elongation which would affect the total pull required during test to cause complete separation of the rubber from the metal.

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[1] See p. 1303.

Laboratory Preparation of Standard Test Specimens

5. For laboratory preparation of test specimens to be used for development and control purposes, the procedure described in the following Paragraphs (*a*) to (*e*) shall be used:

(*a*) Circular metal parts of standard dimensions shall be machined from rolled bar steel, S.A.E. No. 1020, each having on the back face a round stud $\frac{1}{2}$ in. in diameter and $\frac{3}{4}$ in. in length, threaded with 20 threads per inch as shown in Fig. 3. The stud is used for attaching the test piece to the loading fixture in the testing machine. The smoothly machined test faces of the metals shall be brass plated or prepared in accordance with any method for securing adhesion which may be under investigation.

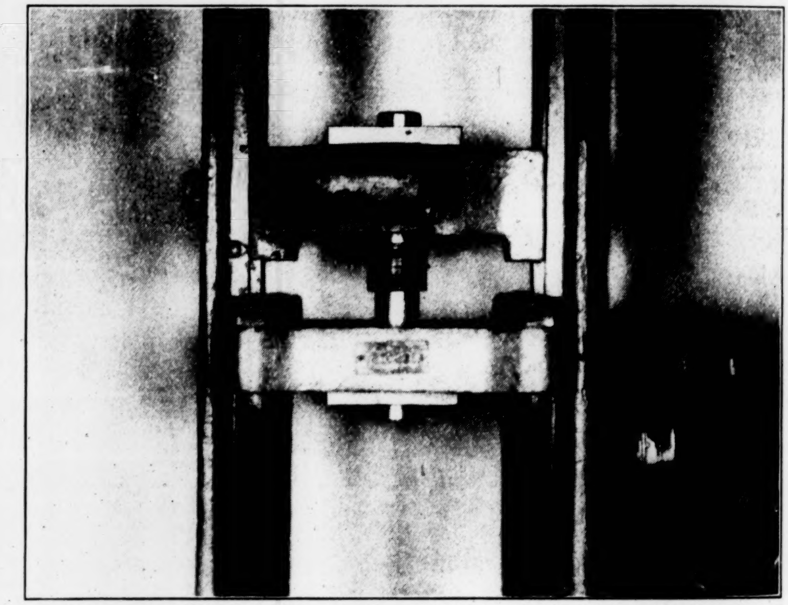

FIG. 2.—Adhesion Test Specimen Attached in Testing Machine.

(*b*) Unvulcanized rubber pieces shall be cut to dimensions of $1\frac{3}{8}$ in. in diameter and $\frac{3}{4}$ in. in thickness so as to give maximum pressure of the rubber against the metal surfaces during vulcanization (see Fig. 1). The surfaces to be adhered shall be washed or treated in accordance with the method being investigated.

(*c*) The metal parts and rubber pieces shall then be assembled for vulcanization in the mold shown in Fig. 3. The method of assembly is illustrated in Fig. 1. The mold is so constructed that there is obtained after vulcanization approximately 0.0015 in. of rubber over the edge of the metal to eliminate tearing of the rubber during test from the sharp edge of the metal. Prior to vulcanization great care shall be taken to keep the surfaces to be adhered clean and free from dust, moisture or other foreign material. The surfaces shall not be touched with the hands.

(*d*) Vulcanization shall be carried out by heating the mold for a definite time at a controlled temperature in a hydraulic vulcanizing press. The time and temperature of cure shall be chosen according to the rubber compound used. At the conclusion of the cure, care shall be taken in removing the specimens from the mold to avoid subjecting the adhered surfaces to stress before the specimens have cooled.

(*e*) After vulcanization the specimens shall be kept at room temperature at least 24 hr. before being tested.

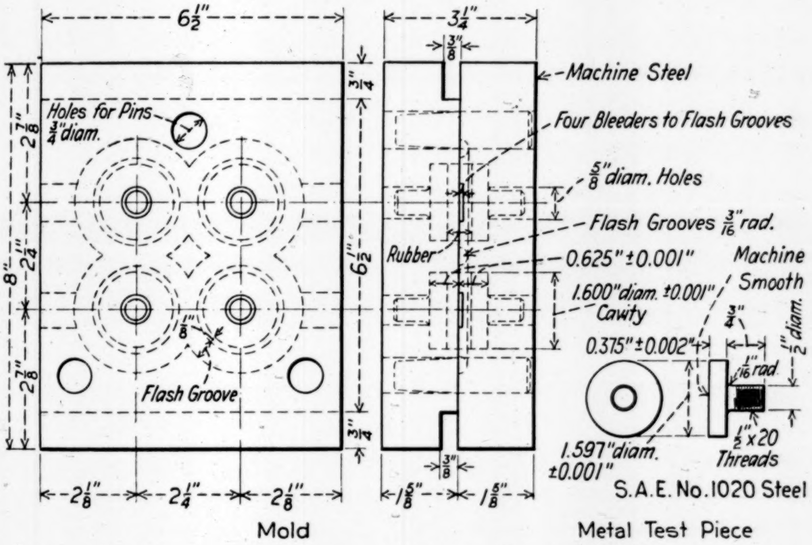
6 1/2"
3 1/4"
3/8"
Machine Steel
Holes for Pins 3/4" diam.
Four Bleeders to Flash Grooves
5/8" diam. Holes
Flash Grooves 3/16" rad.
Rubber
0.625" ± 0.001"
Machine Smooth
1.600" diam. ± 0.001" Cavity
3/4"
0.375" ± 0.002"
1/16" rad.
1/2" diam.
8"
2 7/8"
2 1/4"
2 7/8"
3/4"
6 1/2"
3/4"
1/8"
Flash Groove
1.597" diam. ± 0.001"
1/2" x 20 Threads
S.A.E. No. 1020 Steel
2 1/8"
2 1/4"
2 1/8"
1 5/8"
1 5/8"
Mold
Metal Test Piece

FIG. 3.—Detailed Drawing of Mold for Adhesion Test Pieces.

Preparation of Specimens from Production Parts

6. (*a*) For comparative tests of adhesion in production parts it is necessary to select a portion of the part such that a specimen consisting of a rubber piece sandwiched between two parallel plates of metal may be cut. The specimen shall be hollow-milled out of the production part and turned down to size. Whenever possible, the specimen shall conform to the dimensions of the standard specimen, namely, a thickness of rubber of ½ in. and a diameter of 1.579 in., equivalent to a 2 sq. in. circular cross-section, for both rubber and metal. The metal plates shall be grooved for attachment in the grips as shown in Fig. 4.

(*b*) In routine production testing, it is sometimes necessary to test specimens of different size and shape than those specified as standard. In such cases, the method of preparation shall be similar to that given in

Paragraph (*a*) but the test results secured shall not be compared with those obtained using the standard specimen.

Testing Procedure

7. The vulcanized standard test specimen or the specimen cut from a production part shall be mounted in the testing machine, using care in centering and adjustment so that the tension shall be uniformly distributed. A steady tension load shall then be applied at the specified machine speed until the rubber either separates from the metal surface or ruptures. The total load at the time of failure shall be recorded. In case of rupture in the rubber, the strength of the adhesion bond is obviously not measured, but is shown to be greater than the strength of the rubber itself. Notation to this effect shall be made on the test report. It is usual, however, when high-grade rubber compounds are used, for the failure to occur at the rubber-metal interface and the maximum applied pull then truly evaluates the strength of adhesion.

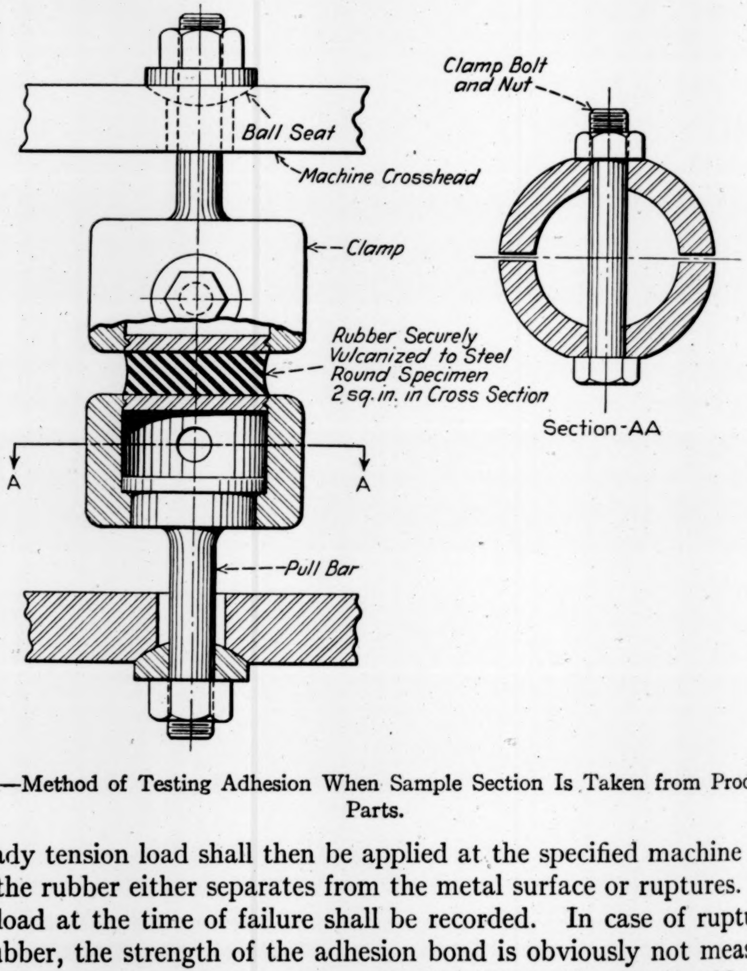
Clamp Bolt and Nut
Ball Seat
Machine Crosshead
Clamp
Rubber Securely Vulcanized to Steel Round Specimen 2 sq. in. in Cross Section
Section-AA
A
A
Pull Bar

FIG. 4.—Method of Testing Adhesion When Sample Section Is Taken from Production Parts.

Check Tests

8. Two tests shall be made and the average value taken if the results check within 100 lb. per sq. in. In the event that the two results fail to check within 100 lb. per sq. in., three additional specimens shall be tested and the average of all five tests shall be reported.

Calculation of Results

9. The adhesion value shall be expressed in pounds per square inch and shall be calculated by dividing the tension load causing failure by the original area of the adhered surface which separates. With the standard specimen, the value is the load at failure divided by two. In case of rupture of the rubber, the value reported is the load at failure divided by the original cross-sectional area of the specimen.

Report

10. The report shall include the following:

(*a*) The result calculated in accordance with Section 9.

(*b*) All observed and recorded data.

(*c*) Notation of the type of separation and statement of whether the results show true adhesion values or strength of the rubber.

(*d*) A description of the specimen including statement of method of securing adhesion if known and notation of whether the specimen was molded in the laboratory or prepared from a production part.

(*e*) Dimensions of the test specimen. Comparisons may only be made between specimens of the same size and shape.

(*f*) Date of manufacture or vulcanization, if known.

(*g*) Time and temperature of vulcanization, if known.

(*h*) Temperature of test room.

(*i*) Date of test.

TENTATIVE METHODS OF TEST
FOR
FLEXING OF RUBBER PRODUCTS[1]

A.S.T.M. Designation: D 430 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These methods are intended for use in estimating the comparative ability of soft rubber compounds to withstand the effect of repeated flexing. They do not apply to the testing of the material ordinarily classed as hard rubber. They are not suited for use in purchase specification requirements both because correlation with service life is uncertain and because the results from duplicate specimens do not check with sufficient precision. No relation between the results of the tests and actual service performance is given or implied. While not accurate measures, they do, however, yield data on which to base a judgment as to service quality and are widely used in research and development work. When properly applied and interpreted, the tests give comparative results of unquestioned value.

Types of Tests

2. (*a*) Flexing tests are designed to simulate the continually repeated distortions received in service by many rubber articles, such as tires, belts, footwear and various molded goods. These distortions may be produced by extending, compressing and bending forces or combinations of them. The effect of the distortions is to weaken the rubber until surface cracking or actual rupture occurs. In the case of combinations of rubber with other flexible material such as fabric, the effect may be evidenced by separation between the materials, caused either by breaking of the rubber or failure of the adhesion or both.

(*b*) Flexing tests are, therefore, of the following two types:

Type I.—Tests designed to produce separation of rubber-fabric combinations such as are used in belts and tires, involving controlled bending of the specimens.

Type II.—Tests designed to produce flex-cracking on the surface of rubber by either bending or extension as occurs in service with parts such as tire treads and sidewalls, rubber soles and shoe uppers, diaphragms, hose covers, etc.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-11 on Rubber Products.

[2] Accepted for publication as tentative by Committee E-10 on Standards, September 28, 1935.

(*c*) These methods cover the following three test procedures using different types of apparatus:

Method A. Scott Flexing Machine Test.
Method B. De Mattia Flexing Machine Test.
Method C. E. I. du Pont de Nemours and Co. Flexing Machine Test.

The Scott flexing machine is used principally for tests of Type I, the De Mattia flexing machine for tests of Type II, while the du Pont apparatus is adapted to tests of either Type I or II.

3. Except as may be otherwise specified in these methods, the requirements of the Tentative Methods of Physical Testing of Rubber Products (General Requirements) (A.S.T.M. Designation: D 15 - 35 T) of the American Society for Testing Materials[1] shall be complied with and are made a part of these methods.

4. In case of conflict between the provisions of these methods and those of detailed specifications or methods of test for a particular material, the latter shall take precedence.

Method A. Scott Flexing Machine Test[2]

Type of Flexure

5. The Scott flexing machine method is used to test for ply separation samples of belts, tires or other articles composed of plies of fabric bonded together by rubber compounds.

Belt Test Specimens

6. Test specimens selected from samples of belts shall be cut lengthwise of the belt and their locations recorded. The seam area of a folded belt shall not be included in any of the test specimens and the folded edge shall be removed before cutting the specimens. The specimens shall consist of four plies for routine tests, any excess plies being removed by stripping carefully so as not to weaken the remaining bonds. The specimens shall be 8.250 in. in length by 1 in. $\pm\frac{1}{128}$ in. in width. The actual thickness shall be measured and recorded.

Tire Test Specimens

7. Suitable test specimens cannot be cut from finished tires and it is necessary to prepare special flexing pad samples as described in the following

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[1] See p. 1153.

[2] Method *A* was originated by General Laboratories, U. S. Rubber Co. For further information respecting this test see W. A. Gibbons, "Flexing Test for Tire Carcass Stocks," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 2, No. 1, p. 99, January 15, 1930; also W. L. Sturtevant, "Rubber Power Transmission Belting, Part III—Flexing Machine and Pynamometers for Testing Belting Quality," *India Rubber World*, Vol. 83, No. 3, p. 67 (1930).

Paragraphs (*a*) to (*c*) from the cord fabric and rubber compounds which are to be tested:

(*a*) *Building Unvulcanized Flexing Pad Sample.*—Solutioned, frictioned or bare cord fabric shall be calendered with the rubber compound to a total thickness of 0.050 in. Six plies of this material shall be assembled using a hand roller so that the plies run in alternate directions. The first, third and fifth plies shall have the cords lengthwise and the second, fourth and sixth plies crosswise of the pad. Care shall be taken that the same calendered side of each piece is facing up and that each alternate ply crosses at right angles. The pad which then has a thickness of 0.300 in. shall be cut by means of a template and knife to dimensions of 4.94 by 7.94 in. The long edge of the template shall be held parallel with the lengthwise cords in the pad.

(*b*) *Vulcanizing of Flexing Pad Samples.*—The flexing pad sample shall be vulcanized in a steel mold having a cavity measuring 5 by 8 by 0.325 in. Uniform compression shall be applied over the entire top surface of the pad. This compression, together with slight stretching produced by the unvulcanized pad being cut slightly smaller than the cavity, ensures straight cords in the cured pad. In order to obtain the compression it is necessary to make up the difference between the pad thickness and the mold depth by means of filler layers of holland cloth or tin foil which are placed on top of the pad. These filler layers shall be added until the total thickness of the assembly, measured by means of a dial micrometer gage using a little pressure with the fingers on both sides of the gage foot, is 0.305 in. A sheet of rubber compound containing curing ingredients and measuring 6 by 9 by 0.02 in. shall be placed on top of the flexing pad and filler layers over the cavity of the mold before the mold cover is placed in position. The total thickness of the material in the mold is then 0.325 in. and expansion will produce the correct pressure to make a compact, undistorted pad. The purpose of the top rubber layer is to fill the overflow space and seal the mold. In placing the flexing pad in the mold, care shall be taken to keep uppermost that side of the pad having the cords running crosswise. Vulcanization shall be carried out by heating the mold under pressure at a known temperature for the required time in a rubber vulcanizing press. After curing, the filler layers shall be removed and the pad allowed to cool and rest at a room temperature between 70 and 90 F. (21 and 32 C.) for not less than 36 hr. before being tested. Pads made in this manner shall be 8 in. in length by 5 in. in width and shall have a thickness of 0.275 to 0.280 in. Any pads having wrinkled cords shall not be tested.

(*c*) *Cutting Tire Test Specimens.*—Four strips each 8 in. in length by 1 in. in width shall be cut from the tire flexing pad. On the first cut, a strip 0.250 to 0.500 in. in width from the edge along the long side of the pad shall be removed and discarded. Care shall be taken to cut the strips straight, with smooth edges and as closely to the exact width as possible. If reasonable care has been taken in preparing the pads and in cutting the specimens, there should not be more than five or six cut longitudinal threads showing on the two edges of a six-ply specimen. An excessive number of such cut threads indicates that many of the threads of alternate plies are not parallel.

Number of Test Specimens

8. At least five specimens from each belt sample or four specimens from each tire pad shall be tested and the results averaged. The accuracy of the final value may be increased by testing a greater number of specimens.

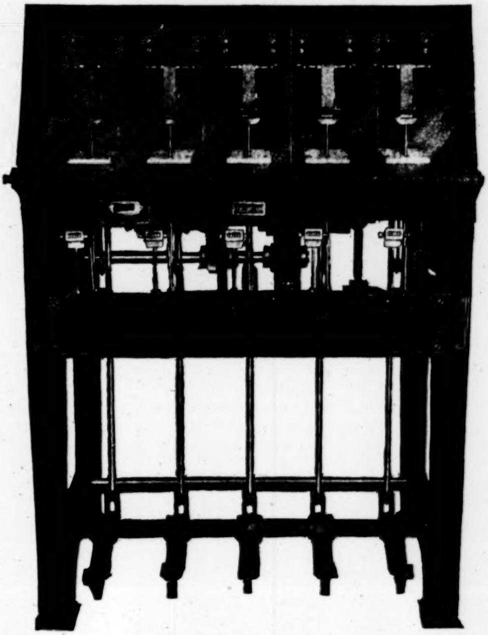

FIG. 1.—Scott Flexing Machine with Five Hubs.

Scott Flexing Machine

9. The essential features of the apparatus, illustrated in Fig. 1, are as follows: The flexing machine shall have five hubs and be capable of testing five specimens at one time. Each hub shall be carried on a loading lever and shall rotate on suitable bearings. The test specimens shall be bent around the hubs having an arc of contact of about 135 deg. and the ends shall be gripped by clamps which are oscillated up and down by rocker arms driven through a chain of gears by a $\frac{1}{4}$-hp., 1750 r.p.m. motor. The action on the specimen shall be a flexing back and forth over the hub

while pulled taut by the loading lever and weight. The specimen shall have a travel in one direction of 2.625 in. and a full cycle travel of 5.250 in. The speed of operation shall be approximately 160 cycles per minute, the exact number of cycles in each test being recorded on a counter affixed to each rocker arm. The entire machine is approximately 50 in. high and occupies a floor space of about 26 by 38 in.

Hub Size and Flexing Load

10. Belt test specimens shall be run using hubs 1.250 in. in diameter and a 100-lb. flexing load. Cord tire specimens shall be run using hubs 0.563 in. in diameter and a 100-lb. flexing load.

Belt Test Procedure

11. The belt test specimens shall be bent around the hubs with the pulley side of the belt against the metal and the ends clamped in the grips. The flexing load shall be then carefully applied without shock, the counter set at zero and the machine started. It shall be allowed to run until some fine particles dislodged by friction may be seen on the white plate beneath the hub which indicates that separation of the plies has started. Frequent inspection of the specimens undergoing test is imperative if reliable results are to be expected. When the first indication of ply separation appears, the counter reading shall be noted and thereafter the specimen shall be more closely watched and the frequency of the inspection increased to ensure proper determination of the end-point. When there is a clear separation across the width of the specimen it shall be considered to have failed. The minimum counter reading for this failure shall be recorded as the end-point. Notation shall also be made as to the location of the separation. When a test is started, it shall be continued to completion without interruption. The machine shall not be stopped and allowed to remain inactive for any length of time and then started again. However, for examining the specimen, each hub may be released momentarily from its weight by means of the foot lever provided. None but experienced operators should make this determination.

Tire Carcass Test Procedure

12. The tire test specimens shall be mounted with the lengthwise outer ply cords against the hub of the machine and shall be tested in a manner similar to the procedure for belts (Section 11). In the case of tire specimens, after the specimen has been run about 10 min. a thick coat of molten caranauba wax shall be brushed on the outer side of the specimen at the flexing region. As soon as separation begins, the temperature of this section increases very rapidly and the wax melts. The melting of the wax starts with a small area and gradually spreads as separation increases. This serves as a warning that complete separation will occur shortly there-

after and eliminates the necessity of examining the specimen at frequent intervals during the early part of the test. The interval between the melting of the wax (the time at which separation actually starts) and complete separation across the specimen may not always be the same (Note).

NOTE.—A specimen with a short flexing life will show complete separation soon after the wax melts, whereas, a sample with a greater flexing life might require a time interval two or three times as long. However, with specimens having similar flexing life, the time interval between the melting of the wax and complete separation is fairly constant.

Test Results

13. The result of the test of any sample shall be calculated as the average of the number of flexing cycles required to produce complete separation of each test specimen as determined from the counter readings.

Method B. De Mattia Flexing Machine Test[1]

Type of Flexure

14. The De Mattia flexing machine method may be used to test rubber specimens for resistance to flex cracking produced either by extension or bending, depending on the relative adjustment of the stationary and movable grips and the distance of travel of the latter. The choice of type of flexure is optional (Note) but notation shall be made of the type actually used, giving full details of the relative positions of the grips and of the travel.

NOTE.—In choosing the type of flexure, it should be remembered that the phenomenon of flex cracking starts on the surface of the rubber and rapidly progresses inward as new surface is exposed. Since rubber is practically non-compressible but highly extensible, the rupture of the surface fibers in both types of flexure must come from disturbances due to elongation. The magnitude of the extension, however, may differ and the internal distribution of force in the specimens is not the same in the two cases. The choice, therefore, will depend considerably on the purpose of the test and the kind of service for which correlation of the test results may be sought.

Test Specimens for Extension Flexing

15. When extension flexing is used the standard test specimen shall be the dumb-bell shaped tension specimen shown in Fig. 3 (Die C) of the Tentative Methods of Tension Testing of Vulcanized Rubber (A.S.T.M. Designation: D 412 - 35 T) of the American Society for Testing Materials.[2] The actual thickness shall be measured and recorded and results shall only be compared when obtained using specimens of substantially the same thickness. The specimens shall be prepared in the same manner as for tension tests and special care shall be taken to avoid any surface imperfections which might start the cracking. All specimens with irregularities on any surface shall be discarded. On specimens cut from molded sheets, highly polished surfaces are very desirable. When buffing is neces-

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[1] See L. V. Cooper, "Laboratory Evaluation of Flex-Cracking Resistance," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 2, No. 1, p. 391, October 15, 1930.

[2] See p. 1159.

sary, as with samples cut from finished products, great care shall be exercised that the buffing is alike on all specimens which are to be compared.

Test Specimens for Bend Flexing

16. When the flexure is by bending, special molded specimens of the shape shown in Fig. 2 shall be used. The specimens shall have highly polished surfaces and shall be free from surface irregularities which might start the cracking prematurely. The minimum thickness in the circular groove shall be measured in thousandths of an inch and recorded. Results shall be compared only between specimens having thicknesses agreeing within ±0.0015 in.

Number of Test Specimens

17. At least three specimens from each sample shall be tested and the results averaged. It is desirable, when possible, to test simultaneously with each set of specimens a set of control specimens of which the resistance to flex cracking is known.

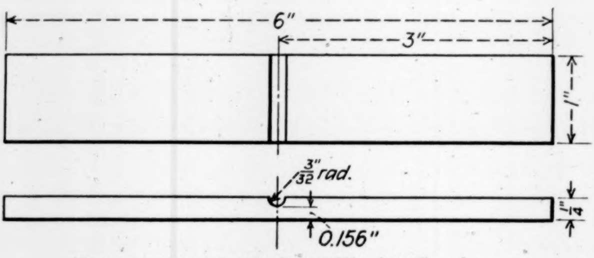

FIG. 2.—De Mattia Bend Flexing Specimen.

De Mattia Flexing Machine

18. The essential features of the apparatus, one design of which is shown in Fig. 3, are as follows: The machine shall have an adjustable stationary head or member provided with suitable grips for holding one end of each of the test specimens in a fixed position and a similar reciprocating member for holding the other end of each of the specimens. The reciprocating member shall be so mounted that its motion is straight in the direction of and in the same plane as the center line between the grips. The travel of the moving member shall be adjustable and shall be obtained by means of a connecting rod and eccentric having a minimum length ratio of 10 to 1. The eccentric shall be driven by a motor operating at constant speed under load and giving 300 flexing cycles per minute. Provision shall be made for a maximum travel of the moving grips of 4 in. The capacity of the machine shall be such that tests at the same time may be made on at least six and preferably twelve specimens. The grips shall hold the specimens firmly throughout the test and those on the reciprocating member may clamp each specimen individually to facilitate proper adjustment of the specimens.

Clamping Specimens in Machine

19. One end of the specimen shall be clamped in the stationary grip and the other in the movable grip, care being taken to see that the long axis of the specimen is parallel to the direction of motion. The constricted section or the circular groove of the clamped specimens shall be located symmetrically midway between the clamps. The specimens for extension flexing shall be gripped only on the enlarged ends. In the case of the specimens for bend flexing, the clamps shall grip each end over a length of $1\frac{3}{8}$ in. with the side having the circular groove so placed that it will be the outer surface when the specimens are bent.

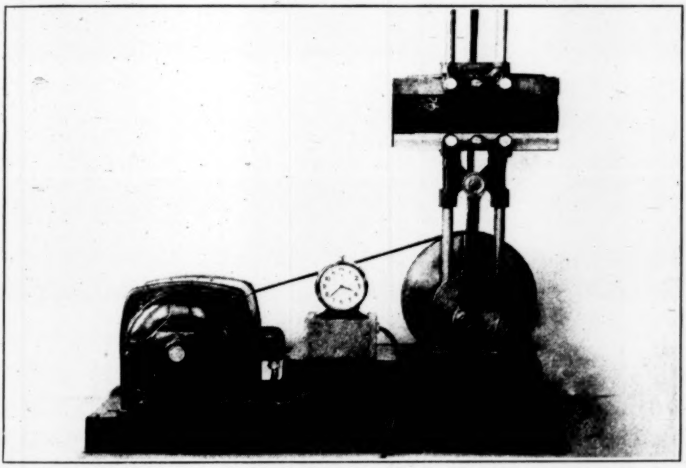

FIG. 3.—De Mattia Tester with Time-Switch for Starting or Stopping, Arranged with Specimens for Flex-Cracking Test.

Adjustment of Machine

20. (*a*) *Extension Flexing.*—For extension flexing tests, the positions of the stationary and movable grips relative to each other and the length of the eccentric arm and connecting rod shall be adjusted by trial so that the movable grip will approach the stationary grip $\frac{1}{2}$ in. closer than necessary to relieve the elongation stress in the specimen and so that the grips will separate a maximum distance sufficient to elongate the portion of the specimen between the gage marks a predetermined and recorded amount. The elongation of the specimens between the gage marks shall not exceed one-fourth of the ultimate breaking elongation. For highly extensible rubbers a maximum elongation of 125 per cent is suitable.

(*b*) *Bend Flexing.*—For bend flexing tests the positions of the stationary and movable grips relative to each other and the length of the eccentric arm and connecting rod shall be adjusted so that during each stroke of the machine the grips approach each other to a distance of $\frac{3}{4}$ in. and separate to a distance of 3 in.

Duration of Test

21. After adjustment of the apparatus and specimens is completed, the machine shall be started and the time recorded. The test shall be continued until, by frequent inspection, the appearance of the first minute sign of cracking is detected when the time shall again be recorded. The first cracking may be evidenced as either very fine hair-line cracks or as slight pin holes. After this time, the specimens shall be observed very closely until the test is discontinued and the final time recorded when the cracks have developed sufficiently to permit grading the degree of the cracking in all specimens as described in Section 22. It is not desirable to flex the specimens until actual complete rupture occurs when this can be avoided. When testing specimens of which the flexing properties are approximately known, the test may be run for a known predetermined number of flexure cycles after which the grading comparison shall be made.

Test Results

22. After conclusion of the test, the flexed specimens shall be removed from the machine and evaluated in sequence relative to the seriousness of the cracking by comparison with a standard scale of cracked specimens of the same type. The comparison shall be made by judging visually the length, depth and number of cracks. The standard comparison scale shall consist of ten specimens equally graded and numbered from No. 0, showing no cracking, to No. 10, which is completely cracked through. The final result for a given sample shall be recorded as the average of the numbers so obtained from all of the specimens. The number of flexures required for the first sign of cracking and for the final result shall be calculated by multiplying the observed flexing time expressed in minutes by the flexing rate of 300 cycles per minute and shall also be recorded. The test results shall be compared only between specimens of similar sizes and shapes, flexed in the same manner under identically the same conditions.

Method C. E. I. du Pont de Nemours and Co. Flexing Machine Test[1]

Test Specimens for Ply Separation

23. Specimens for tests of Type I (Section 2 (*b*)) shall be prepared as in Method *A* and described in Sections 6 and 7 (*a*), (*b*) and (*c*), except that they shall be cut to dimensions of 1 in. in width by 4 in. in length.

Test Specimens for Flex Cracking

24. Specimens for tests of Type II (Section 2 (*b*)) shall be specially prepared from the unvulcanized rubber compounds to be tested. They shall have a fabric base to prevent stretching during test and shall be strips 1 in. in width by 4 in. in length cut at right angles to the grooves from

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[1] Method *C* was originated by Fisk Rubber Co. Laboratories. For further information respecting this test see A. M. Neal and A. J. Northam, "Some Factors Affecting the Resistance to Flexing," *Industrial and Engineering Chemistry*, Vol. 23, No. 12, p. 1449, December, 1931.

vulcanized test slabs prepared as described in the following Paragraphs (*a*) and (*b*):

(*a*) The unvulcanized stock shall be prepared in sheets having a thickness of 0.185 in. ±0.003 in. A slab 4 by 7½ in. shall be cut so that the grain of the stock runs parallel to the 4-in. side. The slab shall then be backed with a layer of frictioned belt fabric cut to the same size. The warp of the fabric shall be placed parallel to the grain of the stock. Semicured white letters may be placed along the side of the slab for the identification of the samples, which shall be subsequently cut out and assembled for flexing. Before vulcanizing, the stock shall be allowed to rest 16 hr. after mixing. The slab and fabric shall conform to the following requirements:

Stock thickness	0.185 in. ± 0.003 in.
Weight of slab (1.15 sp. gr.), approximate	105 g.
Weight of fabric	25 g.
Total weight	130 g.
Overflow, approximate	15 g.

	Warp		Filler
Raw Fabric, Silver Hard Duck:			
Threads per inch	27½	by	18½
Ply	7	by	4
Crimp	25	by	4 per cent
Strength (A.S.T.M. Grab Method),[a] 12-hr. exposure in an atmosphere having a relative humidity of 65 per cent at 70 F.	600	by	290 lb.
Thickness	0.057 in.		
Weight per square yard	28 oz.		
Frictioned Fabric (frictioned both sides):			
Weight per square yard	36 oz.		
Thickness	0.049 in. ± 0.003 in.		

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[a] The Grab Method is described in Section 12 (*b*) of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

(*b*) The stretch is not taken out of the fabric, but this is of little importance since there is little stretch to silver hard duck. The fabric shall be frictioned on both sides with a conventional gum-friction compound. The slab shall be placed in the mold shown in Fig. 4 with the rubber side of the slab next to the mold corrugations and vulcanized as required for the particular compound. This produces a cured slab with a fabric backing 7.5 in. in length by 4 in. in width and 0.188 in. in thickness at the smooth portion and 0.233 in. in thickness at the corrugated portion. There are eight transverse "V" shaped grooves 0.156 in. ($\frac{5}{32}$ in.) in width and 0.045 in. in depth. The angle of the "V" is 120 deg. Notation shall be made of the time and temperature of vulcanization.

Number of Test Specimens

25. At least five specimens from each sample shall be tested in ply separation tests or at least three specimens from each test slab in flex cracking tests and the results averaged. The accuracy of the final value

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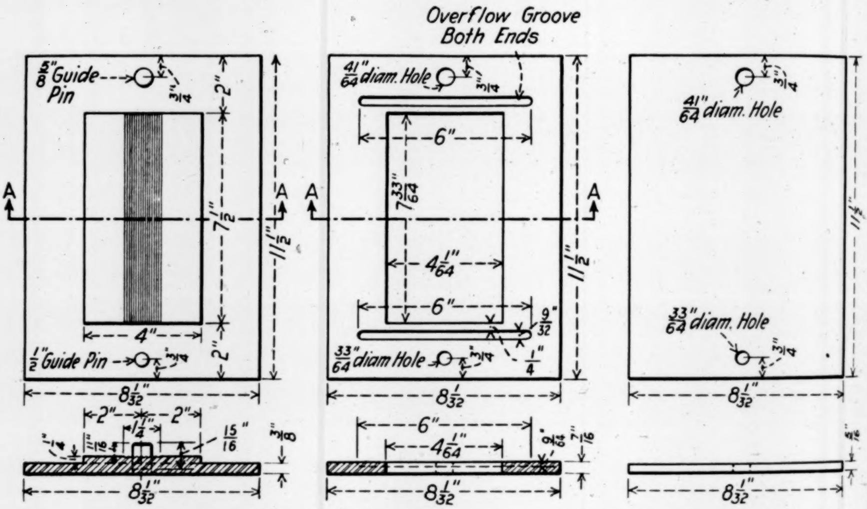
[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 204.

may be increased by testing a greater number of specimens. Since the test is primarily comparative, a set of control specimens from samples of which the qualities are known should be tested simultaneously whenever possible. Flex cracking results shall be compared only between specimens having thicknesses agreeing within ±0.0015 in.

du Pont Flexing Machine

26. The du Pont flexing machine, shown in Fig. 5,[1] consists essentially of four pulleys around which a test belt is run. The belt shall be composed of test specimens acting as links held together with belt fasteners. The machine may be arranged as shown so that several separate belts made of test specimens may be run at the same time. Facing the front of the machine, the upper left-hand pulley shall be driven by a ½-hp. motor. This driving pulley shall have a speed of 930 r.p.m. The upper right-hand pulley shall be on a balance arm which supports a 15-lb. weight. The weight shall be 11 in. and the pulley 5 in. from the supporting pin, producing a belt tension of approximately 33 lb. The center and lower pulleys are idlers. All pulleys shall be 3 in. in outside diameter and shall have faces 1½ in. in width with 0.031 in. ($\frac{1}{32}$ in.) crowns and be mounted on ball bearings. The bottom and center pulleys shall be on the same vertical line and their centers shall be 14¾ in. apart. The left-hand, or driving pulley, and the right-hand, or balance pulley, shall be located 6 in. on either side of the center pulley and 9 in. above it. The specimen belt shall run over the driving pulley, under the center pulley, over the right-hand, or



Base Plate Stripper Plate Top Plate

FIG. 4.—Mold for Preparing Test Specimens for du Pont Flexing Test.

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[1] Blueprints of detailed drawings for the construction of this apparatus are available from the Headquarters of the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

balance pulley, and under the bottom pulley back to the driving pulley. The angle of approach to the pulleys shall be 14 deg. from the vertical. In order to determine when a belt breaks the lever arm shall contact a switch which stops an electric clock.

Test Procedure

27. Twenty test specimens shall be formed into a test belt by means of belt fasteners[1] using six clips on one end of each specimen and five on the other. The belt fasteners shall be joined together with raw-hide pins each 1.125 in. in length. If the number of specimens to be tested is insufficient, blanks of the same size as the specimens may be used. When completed, the belt should measure about 90 in. in circumferential length. The belt shall be placed on the pulleys and driven at a speed of 97 r.p.m. or a linear speed of approximately 8.75 m.p.h. Belts for ply-separation tests shall have the same side of the specimens next to the drive pulley in all cases and when the specimens are cut from rubber belting, this side shall

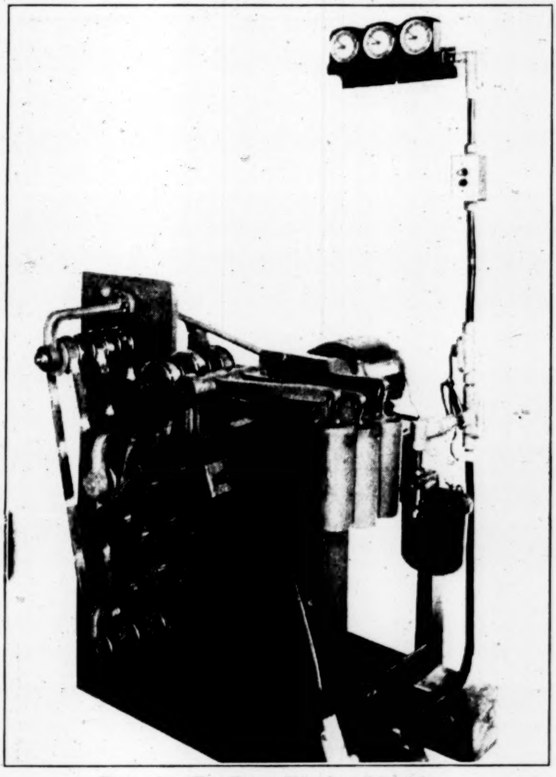

FIG. 5.—Du Pont Flexing Machine.

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[1] Detroit No. 5 belt fasteners are satisfactory.

be the pulley side of the sample. Belts for flex-cracking tests shall have the fabric base next to the drive pulley. Each specimen shall be flexed three times with the face under tension and once under compression during each revolution. The direction of rotation of the belt shall be changed every 12 hr. since this gives greater uniformity. Notation shall be made of the time of starting the machine. Flexing shall be continued and visual inspection of the specimens shall be made at periodic intervals until all specimens show some signs of failure when the test shall be discontinued and the time recorded. With ply-separation specimens, notation shall be made of the time of appearance in each specimen of the first indication of ply separation visible upon bending the specimen. Failure of ply-separation specimens shall be accepted when there is clear separation across the width of the specimen. With flex-cracking specimens, the failure is indicated by the appearance in the corrugations of small nicks or pin holes which soon increase in size until they become deep cracks, which may extend all the way across the specimen. The frequency of inspection of the specimens shall be sufficient to give a reliable measure of the failure of the specimen. If a specimen breaks prematurely, it shall be replaced with a blank and the test continued.

Test Results

28. (*a*) *Ply-Separation Tests.*—With ply-separation specimens, the result of the test for a given sample shall be calculated as the average of the total number of belt revolutions required to produce complete separation of each test specimen. Notation as to the location of the separation shall also be recorded.

(*b*) *Flex-Cracking Tests.*—With flex-cracking specimens, the result of the test shall be evaluated as given in Section 22, except that the number of flexures shall be recorded in terms of total belt revolutions at the end of the test calculated by multiplying the observed flexing time expressed in minutes by the belt speed of 97 r.p.m. A detailed permanent record of the cracking in each specimen may be made by indicating on a suitable form the location, number and intensity of the nicks and cracks. Dots may be used for nicks and straight lines for cracks. Very light marks may be used for first indications with heavier marks to indicate increased depth and width of failure.

REPORT

Report

29. For each of the three alternative methods of test, the report shall include the following:

(*a*) The results of the test expressed in accordance with Section 13, 22, or 28.

(*b*) Statement of the purpose of the test and the method used, including a description of the specimen.

(*c*) All observed and recorded data.

(*d*) Description of the sample.

(*e*) Date of manufacture or vulcanization, if known.

(*f*) Date of test.

(*g*) Temperature of the test room.

TENTATIVE SPECIFICATIONS

FOR

TEXTILE TESTING MACHINES[1]

A.S.T.M. Designation: D 76 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Tension and Elongation Testing Machines

Types of Machines

1. Textile testing machines for the determination of tensile strength and elongation shall be of one of the following general types:

Type A.—The pendulum type.

NOTE.—In Type *A* machine the specimen is strained by a uniform movement of the pulling jaw or clamp to which one end of the specimen is attached, the other end being held in a jaw or clamp attached to a weighing device based on the principle of the pendulum.

Type B.—The constant specimen-rate-of-load type.

NOTE.—In Type *B* machine the load is applied to the specimen at a definite amount of load per unit of time.

Type A Machines

2. (*a*) Machines of Type *A* shall be power-driven, or shall be operated in such a manner that the pulling jaw shall have a speed of 12 ± $\frac{1}{2}$ in. per min., unless otherwise specified.

(*b*) A machine shall be considered to be of proper capacity for a test if, when the specimen breaks, the angle which the pendulum makes with the vertical is between 9 and 45 deg.

(*c*) The minimum pitch diameter of drum for transferring the pull on the specimen to the pendulum shall be 2$\frac{1}{2}$ in.

(*d*) Machines of Type *A* shall be calibrated throughout the loading range of a 9 to 45-deg. swing of the pendulum from the vertical with weights of accurate amounts applied in an ascending order and under machine conditions similar to those specified for the test under consideration.

Type B Machines

3. Machines of Type *B* shall be power-driven or operated in such a

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

These Tentative Specifications are in effect a tentative revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Textile Testing Machines (A.S.T.M. Designation: D 76 - 33), 1933 Book of A.S.T.M. Standards, Part II, p. 1198.

manner that the load shall be applied uniformly at a rate not exceeding 300 lb. per min. for fabrics and for material in the form of skeins.

NOTE.—A calibration method will be developed and added later.

Jaws for Fabric

4. The jaws or clamps for testing a specimen of fabric shall have smooth, flat, metallic, gripping surfaces, with the edges rounded to a radius of not over $\frac{1}{64}$ in. to prevent cutting. One gripping surface shall be hinged or swiveled, and the other shall be rigidly connected to the frame of the jaw. The pressure between the gripping surfaces shall be secured by any suitable mechanical device so constructed as to grip the specimen firmly before the testing load is applied and to prevent slippage during the progress of the test. The dimension of all gripping surfaces parallel to the direction of application of the load shall be 1 in.; the dimension perpendicular to this direction shall be as specified for the particular type of test under consideration.

Jaws for Skein

5. In testing material in the form of a skein, the device for holding the skein shall consist of cylindrical spools not less than 1 in. in diameter and not less than 1 in. in length, so supported that at least one can turn freely on its axis.

Jaws for Individual Strand

6. The jaws or clamps for testing an individual strand of material shall be of the flat grip type, or of the cylindrical or drum type. Those of the latter type shall be so designed that the strand shall pass around not less than 180 deg. of the circumference of the cylinder or drum before being clamped or fixed in the holding device. The length of the specimen shall be considered from center to center of the cylinders or drums. The minimum diameter of the cylinder or drum shall be $\frac{1}{2}$ in.

TENTATIVE GENERAL METHODS OF TEST
FOR
PROPERTIES OF COTTON FIBERS[1]

A.S.T.M. Designation: D 414 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. These methods cover the test procedures for the determination of length, length distribution, fineness, immaturity count, and strength of cotton fibers.

Atmospheric Condition

2. When it is specified that the operations shall be carried out in a "standard atmosphere," an atmosphere having 65 per cent ± 3 per cent relative humidity at 70 F. ± 5 F. (21 C. ± 2.5 C.) shall be considered satisfactory.

LENGTH AND LENGTH DISTRIBUTION

Preparation of Sample

3. (*a*) For making each cotton fiber length array, a composite sample shall be prepared by taking 32 small tufts or pinches from the sample of ginned lint (usually 0.5 to 3.0 lb.) (Note), 16 tufts well distributed from each of the two sides.

NOTE.—The method of selecting these samples from the gin box, from the various types of bales, or from mill products will depend on the purpose of the study and the quantity of the supply of cotton.

(*b*) The two series of tufts shall be arranged in corresponding rows. Each pair of tufts shall be combined, drawn, lapped in the fingers, and divided by splitting gently into two approximately equal parts, one of which shall be discarded. The resulting tufts shall be arranged in two series in corresponding rows.

(*c*) The process described in Paragraph (*b*) shall be repeated with each successive series containing the 8, 4 and 2 tufts. The two resulting tufts shall be combined, drawn and lapped in the fingers to form a composite tuft.

(*d*) The resulting composite tuft shall be gently cleaned of trash, neps, leaf, etc., and the fibers paralleled and straightened by drawing and lapping in the fingers. Care shall be taken to retain all the fibers except those of neps and tangled masses. In case neps and tangled masses constitute an appreciable proportion of the tuft the percentage by weight shall be determined and recorded.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

(*e*) The sample for sorting shall be obtained by separating from one side of this composite tuft a portion sufficient to weigh approximately 75 mg.

Atmospheric Condition

4. The processes of sorting, measuring and weighing shall be performed in a standard atmosphere (Section 2). (Fibers sorted at relative humidities over or under 65 per cent will measure longer or shorter, respectively, than those sorted at 65 per cent relative humidity.)

Sorting, First Transfer

5. (*a*) The 75-mg. sample shall be carefully inserted into one field of combs (Note) so that it extends across the field at approximately right angles, and occupies a width slightly less than that of the fiber forceps.

NOTE.—The method here described is especially adapted to the Suter-Webb duplex cotton fiber sorter but with more or less obvious alteration in procedure may be carried out with two Baer sorters in tandem arrangement or with a Johannsen or other similar sorter provided with two banks of combs.

(*b*) With forceps especially constructed for this purpose, a small portion of the fibers protruding through the teeth of the comb nearest the operator shall be gripped by their free ends, gently and smoothly drawn out of the bundle, and transferred to the tips of the needles in the second field of combs, the fibers being laid straight and parallel and approximately at right angles to the face of the first comb nearest the operator, their gripped ends being released as near this comb as possible. This deposit of fibers shall be carefully pressed down into the needles of the combs with a special presser devised for the purpose.

(*c*) The process described in Paragraph (*b*) shall be continued until all the fibers are transferred, the lower combs of the first field being dropped as the work progresses. Top combs shall be inserted whenever necessary to prevent slippage of fibers not gripped by the forceps. Care shall be exercised not to bind the fibers by the use of too many top combs, nor to press the fibers too tightly into the lower field, for each will result in the breakage of fibers during the transfers.

Sorting, Second Transfer

6. The carriage of the machine shall be revolved through an angle of 180 deg. and a second transfer made as described in Section 5, except that greater care shall be used in aligning the ends of the fibers.

Arraying the Fibers

7. (*a*) The carriage of the machine shall again be revolved through an angle of 180 deg. and successive small "bites" or pulls taken from the extended tips of the fibers and placed individually in successive order and at short intervals of separation on black velvet-covered boards, the operation being continued until all the fibers in the bundle are so transferred. All pulls shall be laid on the boards as straight as possible, with the ends clearly defined to permit of easy measurement. (Careless transfers and excessive slippage of fibers from the bundle will result in pulls with ragged and uneven ends which are very difficult to measure.)

(*b*) The number of individual pulls laid on the velvet boards in a complete fiber length array shall be not less than 50 nor more than 100 for short staple cotton (less than $1\frac{1}{8}$-in. staple) and not less than 80 nor more than 125 for long staple cotton ($1\frac{1}{8}$-in. and longer staple).

Measuring

8. Beginning at the long end of the array, the lengths of the successive pulls on the velvet boards shall be measured to the nearest $\frac{1}{8}$ in. The measurement shall be recorded and the pulls classified by their mid-point lengths expressed in sixteenths of an inch. For example, $\frac{13}{16}$ in. would be the length recorded for all pulls falling within the class interval of $\frac{12}{16}$ to $\frac{14}{16}$ in., while $\frac{1}{16}$ in. would be the length of all fibers shorter than $\frac{1}{8}$ in.

Grouping and Weighing

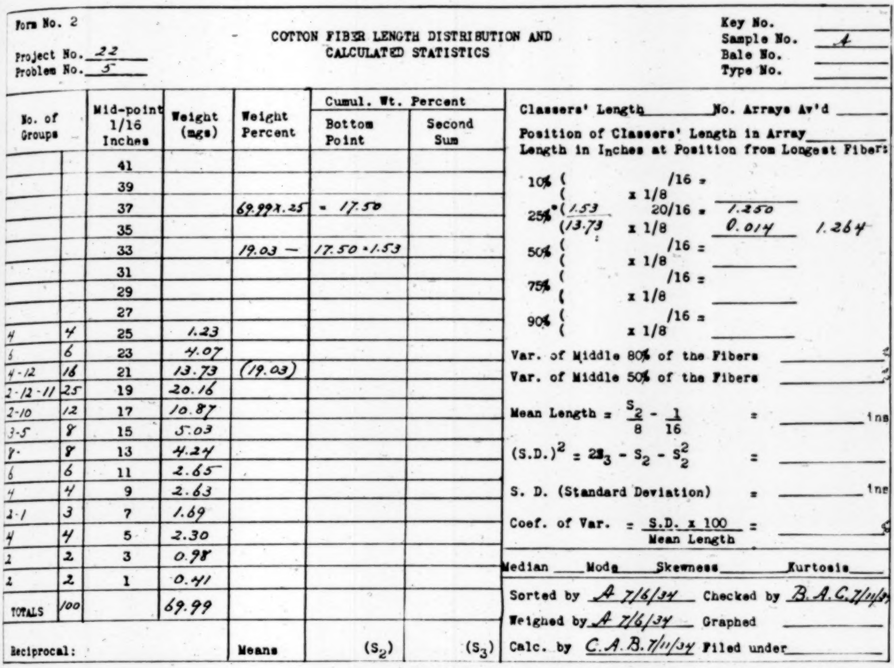
9. The pulls on the velvet boards shall be grouped according to their mid-point length, as established during measuring (see Fig. 1), and weighed to the nearest 0.05 mg. on a torsion or chemical balance graduated to 0.05 mg., and the weight of each group shall be recorded.

Calculations

10. (*a*) The weights for each length group from two or more arrays shall be added for each group. (See Fig. 2.). From these data, calculations shall be made for the percentage by weight of the fibers in each $\frac{1}{8}$-in. length interval, and for the cumulative weight percentage beginning with the longest fibers.

(*b*) The central tendency of the fiber distribution shall be expressed in terms of the upper quartile length (length at the 25 per cent point on the cumulative weight percentage-length curve beginning with the longest fibers), and may also be expressed in terms of modal, mean, median, or percentile length.

(*c*) From the basic data, also shall be calculated the statistical measures known as the mean (weight frequency) length and standard deviation; from these determinations, the coefficient of fiber length variability (the standard deviation expressed as a percentage of the mean) is calculated to indicate the degree of variability of fiber lengths or the concentration of



Form No. 2

Project No. 22
Problem No. 5

COTTON FIBER LENGTH DISTRIBUTION AND
CALCULATED STATISTICS

Key No.
Sample No. A
Bale No.
Type No.

No. of Groups		Mid-point 1/16 Inches	Weight (mgs)	Weight Percent	Cumul. Wt. Percent	
					Bottom Point	Second Sum
		41				
		39				
		37		69.99x.25	= 17.50	
		35				
		33		19.03 —	17.50 = 1.53	
		31				
		29				
		27				
4	4	25	1.23			
6	6	23	4.07			
4-12	16	21	13.73	(19.03)		
2-12-11	25	19	20.16			
2-10	12	17	10.87			
3-5	8	15	5.03			
8-	8	13	4.24			
6	6	11	2.65			
4	4	9	2.63			
2-1	3	7	1.69			
4	4	5	2.30			
2	2	3	0.98			
2	2	1	0.41			
TOTALS	100		69.99			
Reciprocal:				Means	(S_2)	(S_3)

Classers' Length ______ No. Arrays Av'd ______

Position of Classers' Length in Array ______

Length in Inches at Position from Longest Fiber:

10% (/16 =
(x 1/8 ______

25%* (1.53 20/16 = 1.250
(13.73 x 1/8 0.014 1.264

50% (/16 =
(x 1/8 ______

75% (/16 =
(x 1/8 ______

90% (/16 =
(x 1/8 ______

Var. of Middle 80% of the Fibers ______ %

Var. of Middle 50% of the Fibers ______ %

Mean Length = $\frac{S_2}{8} - \frac{1}{16}$ = ______ ins

$(S.D.)^2 = 2S_3 - S_2 - S_2^2$ = ______

S. D. (Standard Deviation) = ______ ins

Coef. of Var. = $\frac{\text{S.D. x 100}}{\text{Mean Length}}$ = ______ %

Median ____ Mode ____ Skewness ____ Kurtosis ____

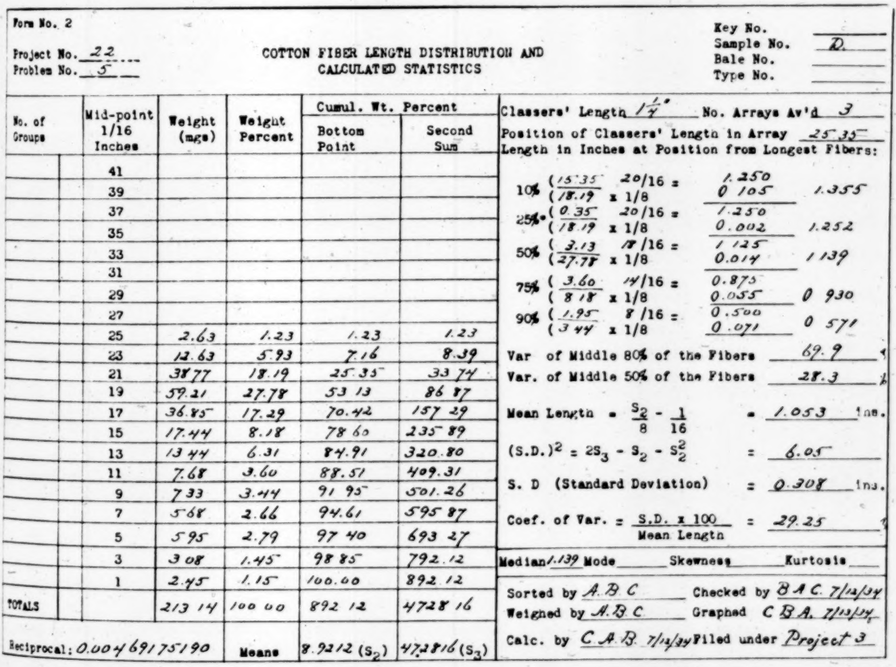
Sorted by A 7/6/34 Checked by B. A. C. 7/11/34

Weighed by A 7/6/34 Graphed ______

Calc. by C. A. B. 7/11/34 Filed under ______

* Upper quartile length.

FIG. 1.—Facsimile of Record Form with Data and Calculations for a Single Cotton Fiber Length Array.



Form No. 2

Project No. 22
Problem No. 5

COTTON FIBER LENGTH DISTRIBUTION AND
CALCULATED STATISTICS

Key No.
Sample No. D.
Bale No.
Type No.

No. of Groups		Mid-point 1/16 Inches	Weight (mgs)	Weight Percent	Cumul. Wt. Percent	
					Bottom Point	Second Sum
		41				
		39				
		37				
		35				
		33				
		31				
		29				
		27				
		25	2.63	1.23	1.23	1.23
		23	12.63	5.93	7.16	8.39
		21	38.77	18.19	25.35	33.74
		19	59.21	27.78	53.13	86.87
		17	36.85	17.29	70.42	157.29
		15	17.44	8.18	78.60	235.89
		13	13.44	6.31	84.91	320.80
		11	7.68	3.60	88.51	409.31
		9	7.33	3.44	91.95	501.26
		7	5.68	2.66	94.61	595.87
		5	5.95	2.79	97.40	693.27
		3	3.08	1.45	98.85	792.12
		1	2.45	1.15	100.00	892.12
TOTALS			213.14	100.00	892.12	4728.16
Reciprocal: 0.004691751 90				Means	8.9212 (S_2)	47.2816 (S_3)

Classers' Length $1\frac{1}{4}$" No. Arrays Av'd 3

Position of Classers' Length in Array 25.35

Length in Inches at Position from Longest Fibers:

10% (15.35 20/16 = 1.250
(18.19 x 1/8 0.105 1.355

25%* (0.35 20/16 = 1.250
(18.19 x 1/8 0.002 1.252

50% (3.13 18/16 = 1.125
(27.78 x 1/8 0.014 1.139

75% (3.60 14/16 = 0.875
(8.18 x 1/8 0.055 0.930

90% (1.95 8/16 = 0.500
(3.44 x 1/8 0.071 0.571

Var of Middle 80% of the Fibers 69.9 %

Var. of Middle 50% of the Fibers 28.3 %

Mean Length = $\frac{S_2}{8} - \frac{1}{16}$ = 1.053 ins.

$(S.D.)^2 = 2S_3 - S_2 - S_2^2$ = 6.05

S. D (Standard Deviation) = 0.308 ins.

Coef. of Var. = $\frac{\text{S.D. x 100}}{\text{Mean Length}}$ = 29.25 %

Median 1.139 Mode ____ Skewness ____ Kurtosis ____

Sorted by A. B. C Checked by B A C. 7/12/34

Weighed by A. B. C Graphed C B A. 7/13/34

Calc. by C. A. B. 7/12/34 Filed under Project 3

* Upper quartile length.

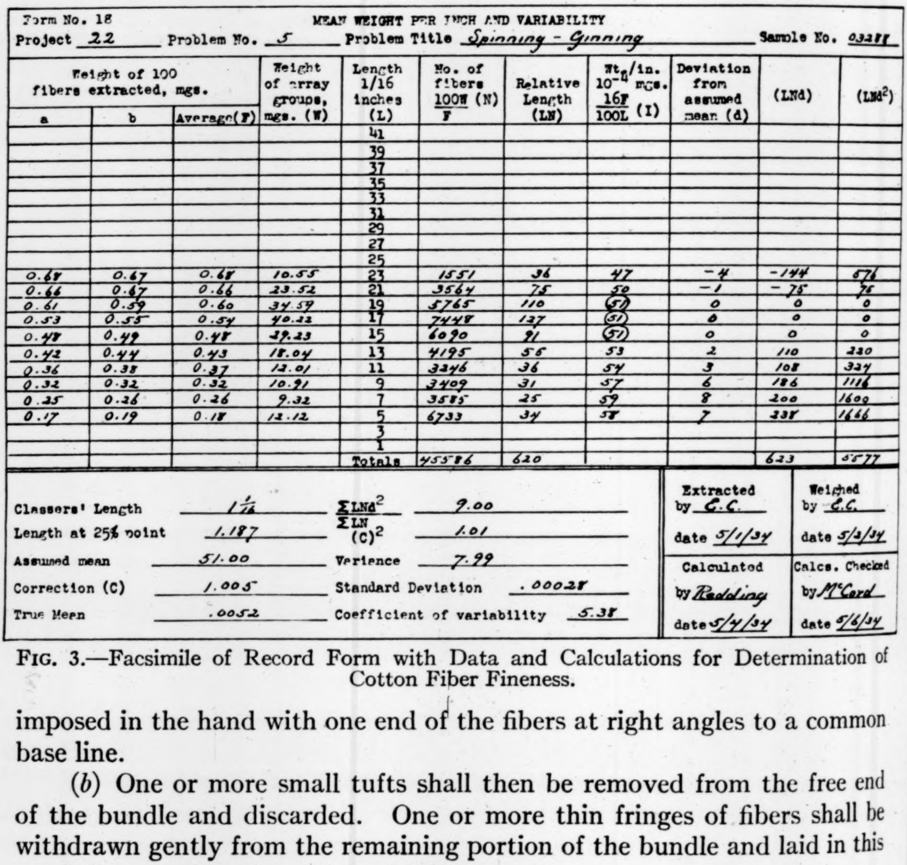
FIG. 2.—Facsimile of Record Form with Combined Data and Calculations for the Average of Three Single Cotton Fiber Length Arrays.

their frequencies. The larger the figure for the coefficient of variability, so calculated, the greater the variability of the fiber lengths in the sample.

FINENESS

Sampling

11. (*a*) The fibers for test shall be taken from not less than two length arrays prepared by the method described in Sections 3 to 9. The two or more assembled groups of corresponding length identifications shall be gently and thoroughly mixed and parallelized by successively pulling and lapping them between the fingers, the pulls in the final process being superimposed in the hand with one end of the fibers at right angles to a common base line.



Form No. 18 MEAN WEIGHT PER INCH AND VARIABILITY

Project 22 Problem No. 5 Problem Title Spinning - Ginning Sample No. 03288

Weight of 100 fibers extracted, mgs.			Weight of array groups, mgs. (W)	Length 1/16 inches (L)	No. of fibers $\frac{100W}{F}$ (N)	Relative Length (LN)	Wt./in. 10^{-4} mgs. $\frac{16F}{100L}$ (I)	Deviation from assumed mean (d)	(LNd)	(LNd^2)
a	b	Average (F)								
				41						
				39						
				37						
				35						
				33						
				31						
				29						
				27						
				25						
0.68	0.67	0.68	10.55	23	1551	36	47	-4	-144	576
0.66	0.67	0.66	23.52	21	3564	75	50	-1	-75	75
0.61	0.59	0.60	34.59	19	5765	110	(51)	0	0	0
0.53	0.55	0.54	40.22	17	7448	127	(51)	0	0	0
0.48	0.49	0.48	29.23	15	6090	91	(51)	0	0	0
0.42	0.44	0.43	18.04	13	4195	56	53	2	110	220
0.36	0.38	0.37	12.01	11	3246	36	54	3	108	324
0.32	0.32	0.32	10.91	9	3409	31	57	6	186	1116
0.25	0.26	0.26	9.32	7	3585	25	59	8	200	1600
0.17	0.19	0.18	12.12	5	6733	34	58	7	238	1666
				3						
				1						
				Totals	45586	620			623	5577

Classers' Length $1\frac{1}{16}$

Length at 25% point 1.187

Assumed mean 51.00

Correction (C) 1.005

True Mean .0052

$\frac{\Sigma LNd^2}{\Sigma LN}$ 9.00

$(C)^2$ 1.01

Variance 7.99

Standard Deviation .00028

Coefficient of variability 5.38

Extracted by C.C. date 5/1/34

Weighed by C.C. date 5/3/34

Calculated by Redding date 5/4/34

Calcs. Checked by McCord date 5/6/34

FIG. 3.—Facsimile of Record Form with Data and Calculations for Determination of Cotton Fiber Fineness.

(*b*) One or more small tufts shall then be removed from the free end of the bundle and discarded. One or more thin fringes of fibers shall be withdrawn gently from the remaining portion of the bundle and laid in this condition on a board covered with black velvet.

(*c*) Two sets of 100 fibers each shall be counted out, starting at one side of the bundle and taking successive fibers.

(*d*) The operations described in Paragraphs (*a*), (*b*) and (*c*) shall be repeated for each identified length group throughout the array, with the exception of the $\frac{1}{16}$ and $\frac{3}{16}$-in. groups, and as many of those beginning at the long end of the array as may be too small to yield two sets of 100 fibers each.

Atmospheric Condition

12. All weighings shall be made in a standard atmosphere (Section 2) and not until after the samples have been conditioned for at least 2 hr. in such an atmosphere.

Weighing

13. Each group of 100 fibers shall be weighed to the nearest 0.01 mg. on a torsion or chemical balance graduated to 0.005 mg. (See Fig. 3.).

Calculations

14. (*a*) The average weight of the two corresponding groups of 100 fibers of each length identification shall be calculated and the mean fiber weight per inch determined.

(*b*) The fineness of a sample shall be the mean fiber weight per inch for the entire sample and shall be determined by mathematically weighting the weight per inch value for each length group on a basis of its contribution of fiber length to the total fiber length of the combined length arrays, and calculating the weighted mean.

(*c*) The coefficient of variability (standard deviation expressed as a percentage of the mean) of fiber weight per inch in the different length groups shall be determined, using the same frequency basis as for the mean fiber weight per inch for the sample, as in Paragraph (*b*).

IMMATURITY COUNT

Sampling

15. The test shall be made on the two sets of 100 fibers each, counted out for each length group as described in Section 11.

Mounting

16. (*a*) The fibers shall be straightened, and placed approximately parallel on a glass slide, covered with a cover slip and flooded with 18 per cent caustic soda.

(*b*) The mount shall be placed on the mechanical stage of the microscope.

Examination

17. The fibers shall be examined near their mid-portion at a magnification of approximately 100 diameters.

Counting and Classifying

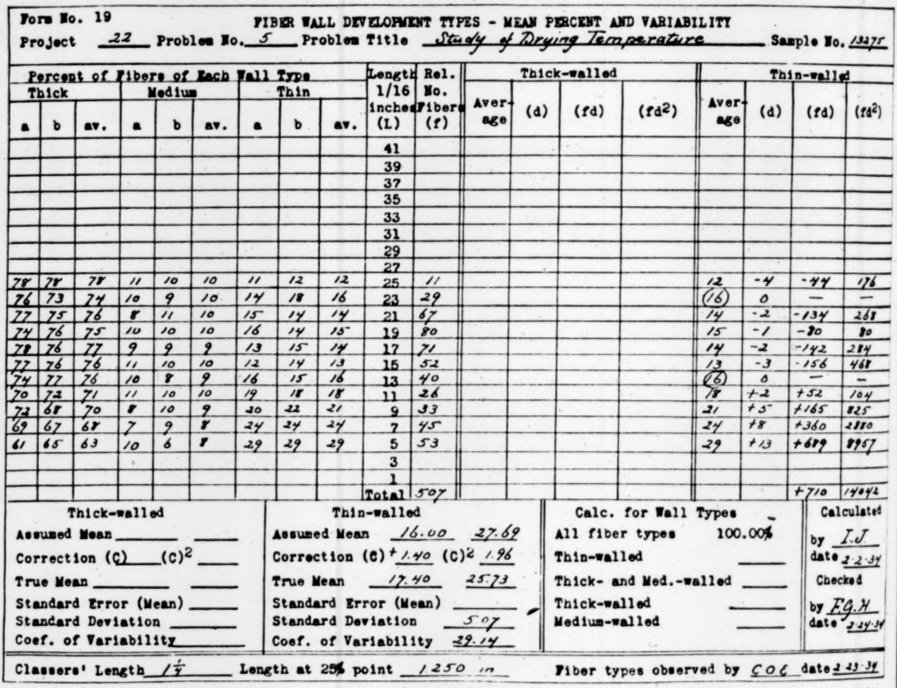
18. (*a*) As successive fibers come into view they shall be counted, and the number of thin-walled or immature fibers in each set determined. (See Fig. 4.)

(*b*) For the purpose of this test, thin-walled or immature fibers are those that upon treatment with 18 per cent caustic soda exhibit many spirals. (Figure 5 shows photomicrographs of thin-walled or immature fibers as compared with medium and thick-walled fibers. The appearance of these fibers before and after treatment is shown for purposes of reference.)

Calculations

19. (*a*) The number of thin-walled or immature fibers of the two groups of 100 fibers each shall be averaged for each length group.

(*b*) A weighted mean of these values, based on the relative number of fibers in each length group of the combined length arrays, shall be calculated for the sample, and shall be the immaturity count. The relative number of fibers in each length group of the length array shall be calculated from the combined weight of the length group and the weight per fiber (see Sections 9 and 13).



Form No. 19 FIBER WALL DEVELOPMENT TYPES - MEAN PERCENT AND VARIABILITY

Project 22 Problem No. 5 Problem Title Study of Drying Temperature Sample No. 13275

Percent of Fibers of Each Wall Type									Length 1/16 inches (L)	Rel. No. Fibers (f)	Thick-walled				Thin-walled			
Thick			Medium			Thin												
a	b	av.	a	b	av.	a	b	av.			Average	(d)	(fd)	(fd^2)	Average	(d)	(fd)	(fd^2)
									41									
									39									
									37									
									35									
									33									
									31									
									29									
									27									
78	78	78	11	10	10	11	12	12	25	11					12	-4	-44	176
76	73	74	10	9	10	14	18	16	23	29					⑯	0	—	—
77	75	76	8	11	10	15	14	14	21	67					14	-2	-134	268
74	76	75	10	10	10	16	14	15	19	80					15	-1	-80	80
78	76	77	9	9	9	13	15	14	17	71					14	-2	-142	284
77	76	76	11	10	10	12	14	13	15	52					13	-3	-156	468
74	77	76	10	8	9	16	15	16	13	40					⑯	0	—	—
70	72	71	11	10	10	19	18	18	11	26					18	+2	+52	104
72	68	70	8	10	9	20	22	21	9	33					21	+5	+165	825
69	67	68	7	9	8	24	24	24	7	45					24	+8	+360	2880
61	65	63	10	6	8	29	29	29	5	53					29	+13	+689	8957
									3									
									1									
									Total	507							+710	14042

Thick-walled
Assumed Mean ________ ____
Correction (C) ____ $(C)^2$ ____
True Mean ________ ____
Standard Error (Mean) ____
Standard Deviation ____
Coef. of Variability ____

Thin-walled
Assumed Mean 16.00 27.69
Correction (C) +1.40 $(C)^2$ 1.96
True Mean 17.40 25.73
Standard Error (Mean) ____
Standard Deviation 5.07
Coef. of Variability 29.14

Calc. for Wall Types
All fiber types 100.00%
Thin-walled ____
Thick- and Med.-walled ____
Thick-walled ____
Medium-walled ____

Calculated
by I.J.
date 2·2·34
Checked
by F.G.H.
date 2·24·34

Classers' Length 1 1/4 Length at 25% point 1.250 in Fiber types observed by COC date 2·23·34

FIG. 4.—Facsimile of Record Form with Data and Calculations for Determination of the Immaturity Count.

(*c*) The coefficient of variability (standard deviation expressed as a percentage of the mean) of fiber immaturity count in the different length groups shall be determined, using the same frequency basis as for the mean immaturity count of the sample as in Paragraph (*b*).

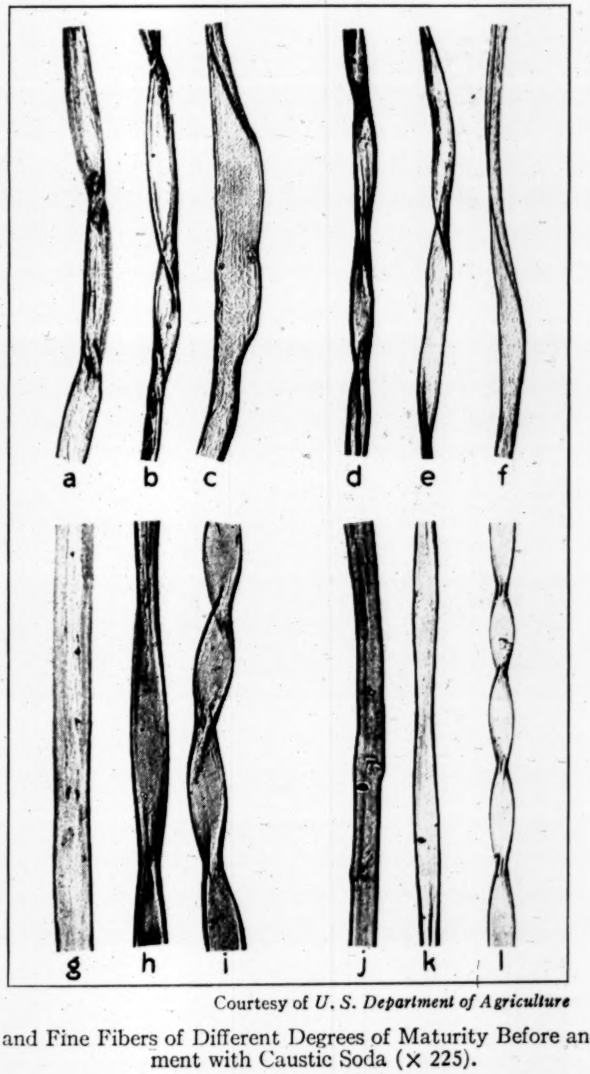
STRENGTH

Atmospheric Condition

20. Sampling, combing, wrapping and breaking shall be performed in a standard atmosphere (Section 2) and not until after the samples have been conditioned for at least 2 hr. in such an atmosphere.

Sampling

21. (*a*) A small handful of cotton shall be removed carefully from the original sample (see Note, Section 3 (*a*)), divided into two approximately equal portions by pulling apart in the hands, and the portions superimposed with their broken surfaces coinciding.



Courtesy of *U. S. Department of Agriculture*

FIG. 5.—Coarse and Fine Fibers of Different Degrees of Maturity Before and After Treatment with Caustic Soda (× 225).

Specimens *a*, *b* and *c* represent thick, medium-thick, and thin-walled fiber types, respectively, from a coarse American upland cotton, staple length $\frac{3}{4}$ in.; *g*, *h* and *i*, the same fibers as *a*, *b* and *c* after treatment with 18 per cent caustic soda solution.

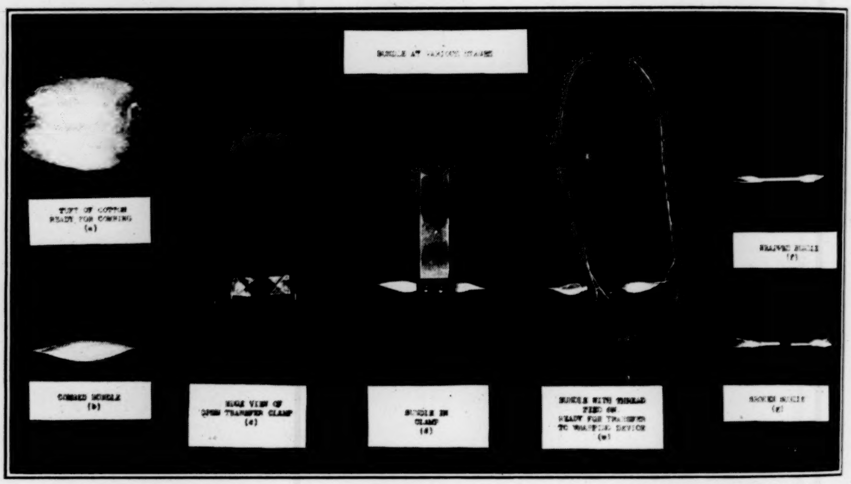
Specimens *d*, *e* and *f* represent thick, medium-thick, and thin-walled fiber types, respectively, from a fine American upland cotton, staple length $1\frac{3}{8}$ in.; *j*, *k* and *i* the same fibers as *d*, *e* and *f* after treatment with 18 per cent caustic soda.

(*b*) From the broken surface of the sample, three to four pulls shall be drawn out with the hand and combined. (See Fig. 6 (*a*).)

(*c*) The operations described under Paragraphs (*a*) and (*b*) shall be repeated for each of the ten bundles required for the complete test.

Combing

22. (*a*) Two stationary combs shall be used, a coarse comb about 2.5 in. in width with needles 0.025 in. in diameter at the base, 0.5 in. in length, and 16 needles to the inch, and a fine comb 2.0 in. in width with needles 0.015 in. in diameter at the base, 0.5 in. in length and, 48 needles to the inch.


BUNDLE AT VARIOUS STAGES
TUFT OF COTTON READY FOR COMBING (a)
COMBED BUNDLE (b)
EDGE VIEW OF OPEN TRANSFER CLAMP (c)
BUNDLE IN CLAMP (d)
BUNDLE WITH THREAD TIED ON READY FOR TRANSFER TO WRAPPING DEVICE (e)
WRAPPED BUNDLE (f)
BROKEN BUNDLE (g)

Courtesy of *U. S. Department of Agriculture*

FIG. 6.—Stages in the Preparation of the Chandler Bundles.

(*b*) The fibers shall be carefully straightened and paralleled by gripping the tuft of fibers (see Fig. 6 (*a*)) near its center with the thumb and forefinger and combing thoroughly. The outer edge of the tuft shall be drawn through the coarse comb and the action gradually advanced toward the center of the tuft, using fifteen strokes through the comb. The tuft then shall be reversed, the combed end grasped about $\frac{1}{8}$ in. inside of the combed position, and the other end combed fifteen times, the combings being discarded.

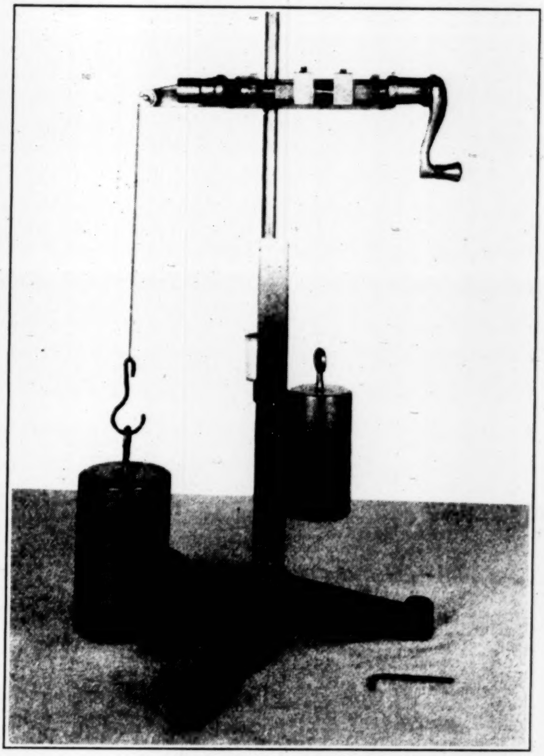
(*c*) The roughly prepared bundle shall be more completely combed by drawing each end through the fine comb 20 times, after which the bundle shall be adjusted in size by separating as many fibers from the side as may be necessary to give a wrapped bundle with a corrected circumference within the range 0.115 to 0.135 in. (The correct range of circumference may easily be attained with the aid of a torsion balance of a 50-mg. capacity.)

(*d*) The bundle then shall be finished on the fine comb by stroking each end fifteen times.

Wrapping

23. (*a*) Each bundle shall be wrapped by means of a special wrapping device and process. (See Fig. 7).

(*b*) The bundle shall be inserted in a special clamp (see Fig. 6 (*c*), (*d*), and (*e*)), and the fibers straightened by gently pulling on each end of the bundle.



Courtesy of *U. S. Department of Agriculture*

FIG. 7.—Wrapping Device with Bundle in Jaws and Weights Suspended.

(*c*) Each end of about 20 in. of No. 20 sewing thread shall be tied to opposite ends of the bundle near the sides of the clamp. (See Fig. 6 (*e*).)

(*d*) The bundle, still in the clamp, shall be transferred to and fastened securely in the wrapping device.

(*e*) The bundle shall be stretched lengthwise by tension from a 10-lb. weight suspended over a pulley. The bundle clamp then shall be removed and a 4-lb. weight suspended and allowed to hang freely in the loop of the wrapping thread.

(*f*) The handle of the wrapping device shall be turned about a dozen turns, care being exercised to hold the two threads slightly apart with the fingers of one hand in order that the thread will pack closely during successive turns of the bundle. The handle shall be stopped at an index on its shoulder and the position of the weight hanging freely in the thread shall be recorded. (See Fig. 8.)

(*g*) The wrapping shall be continued exactly ten revolutions of the handle, the threads again being held apart slightly, as before. The fingers then shall be removed from the thread and the new position of the suspended weight recorded.

(*h*) The wrapping shall be continued until the threads meet near the center of the bundle and reverse their course along the bundle. A pencil mark shall be made where the two threads meet. Finally, wrapping shall be continued until the threads reach the sides of the wrapping jaws.

TABLE I.—CORRECTIONS TO APPLY TO MACHINE BREAKS FOR COTTONS OF DIFFERENT STRENGTHS.[a]

Deviation of Corrected Circumference from Standard, in.	Average Machine Break in Pounds of Bundles Corrected to 0.125-in. Circumference										
	80 lb.	85 lb.	90 lb.	95 lb.	100 lb.	105 lb.	110 lb.	115 lb.	120 lb.	125 lb.	130 lb.
0.001	1	1	1	1	1	1	1	1	2	2	2
0.002	2	2	2	2	2	3	3	3	3	3	3
0.003	3	3	3	3	4	4	4	4	5	5	5
0.004	4	4	4	5	5	5	6	6	6	7	7
0.005	4	5	5	6	6	7	7	7	8	8	9
0.006	5	6	6	7	7	8	8	9	9	10	10
0.007	6	7	7	8	9	9	10	10	11	11	12
0.008	7	8	8	9	10	10	11	12	12	13	14
0.009	8	9	10	10	11	12	12	13	14	15	15
0.010	9	10	11	11	12	13	14	15	16	16	17

[a] Bundles smaller than standard circumference require the corrections to be added; those larger than standard require the corrections to be subtracted.

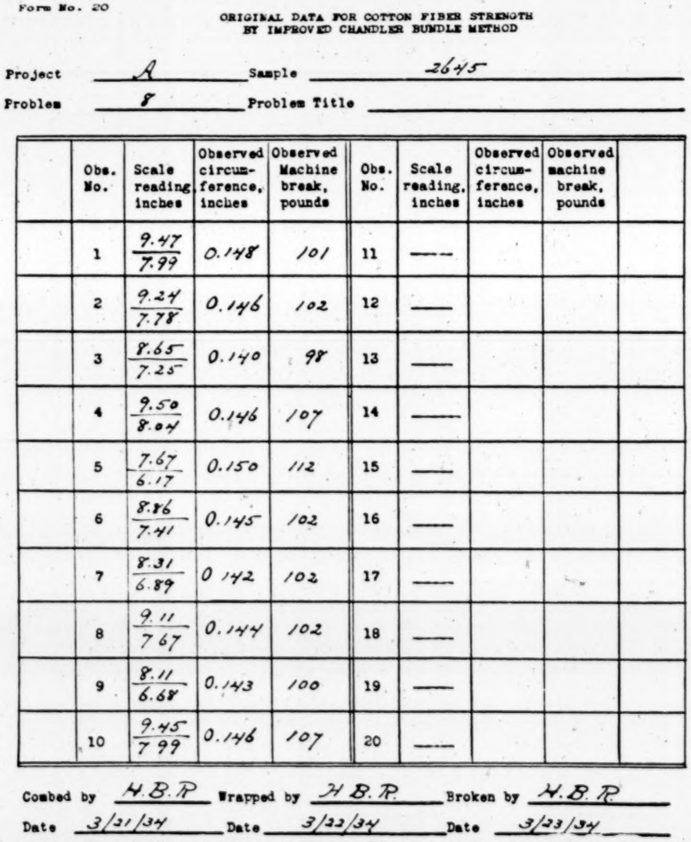
(*i*) The two weights shall be removed. The loop of the thread shall be cut in the center and each end tied around its respective bundle end.

Breaking

24. (*a*) Breaking jaws specially designed and constructed for the purpose shall be used in this test. The essential feature of the jaw is a slot into which is pressed a piece of hard sole leather. A lengthwise groove is made in the center of the leather by partly impressing a wire of $\frac{1}{16}$ in. in diameter.

(*b*) With the special jaws (Paragraph (*a*)) set so that they are in contact, each bundle shall be placed in them so that the mark near the center of the bundle coincides with the point of contact of the jaws.

(*c*) Each bundle, so clamped in the jaws, shall be placed in a tension testing machine with a capacity of 300 lb. and the bundle broken with the pulling jaws moving at the rate of 12 in. ± $\frac{1}{2}$ in. per min. Only a break that is sharp and at the mark on the bundle shall be considered to be successful.



Form No. 20

ORIGINAL DATA FOR COTTON FIBER STRENGTH
BY IMPROVED CHANDLER BUNDLE METHOD

Project A Sample 2645

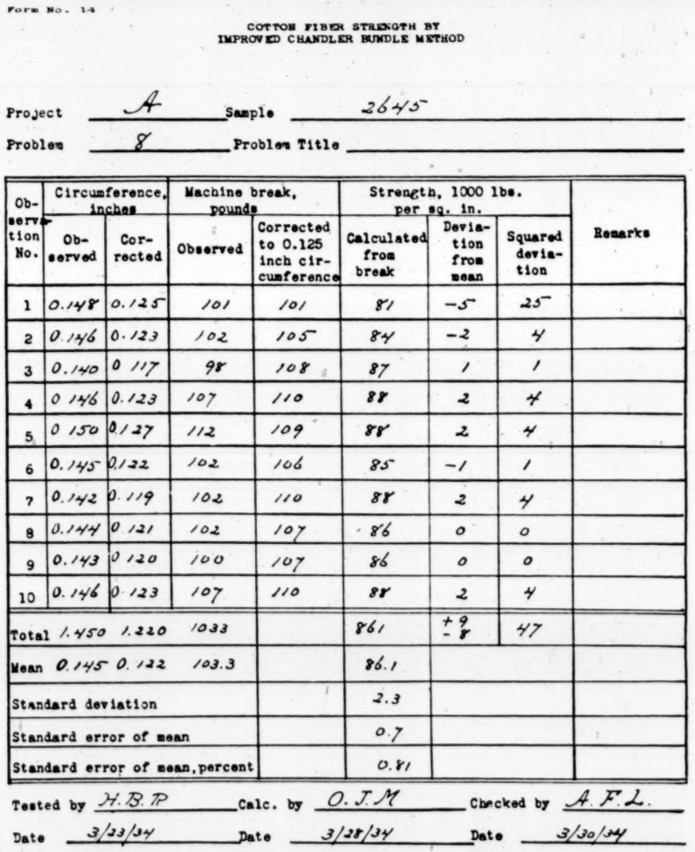
Problem 8 Problem Title

	Obs. No.	Scale reading, inches	Observed circumference, inches	Observed Machine break, pounds	Obs. No.	Scale reading, inches	Observed circumference, inches	Observed machine break, pounds	
	1	$\frac{9.47}{7.99}$	0.148	101	11	——			
	2	$\frac{9.24}{7.78}$	0.146	102	12	——			
	3	$\frac{8.65}{7.25}$	0.140	98	13	——			
	4	$\frac{9.50}{8.04}$	0.146	107	14	——			
	5	$\frac{7.67}{6.17}$	0.150	112	15	——			
	6	$\frac{8.86}{7.41}$	0.145	102	16	——			
	7	$\frac{8.31}{6.89}$	0.142	102	17	——			
	8	$\frac{9.11}{7.67}$	0.144	102	18	——			
	9	$\frac{8.11}{6.68}$	0.143	100	19	——			
	10	$\frac{9.45}{7.99}$	0.146	107	20	——			

Combed by H.B.R. Wrapped by H.B.R. Broken by H.B.R.

Date 3/21/34 Date 3/22/34 Date 3/23/34

FIG. 8.—Facsimile of Record Form Used in the Modified Chandler Bundle Method and Data Representing the Observed Scale Readings and Machine Breaks.



Form No. 14

COTTON FIBER STRENGTH BY
IMPROVED CHANDLER BUNDLE METHOD

Project A Sample 2645

Problem 8 Problem Title

Observation No.	Circumference, inches		Machine break, pounds		Strength, 1000 lbs. per sq. in.			Remarks
	Observed	Corrected	Observed	Corrected to 0.125 inch circumference	Calculated from break	Deviation from mean	Squared deviation	
1	0.148	0.125	101	101	81	−5	25	
2	0.146	0.123	102	105	84	−2	4	
3	0.140	0.117	98	108	87	1	1	
4	0.146	0.123	107	110	88	2	4	
5	0.150	0.127	112	109	88	2	4	
6	0.145	0.122	102	106	85	−1	1	
7	0.142	0.119	102	110	88	2	4	
8	0.144	0.121	102	107	86	0	0	
9	0.143	0.120	100	107	86	0	0	
10	0.146	0.123	107	110	88	2	4	
Total	1.450	1.220	1033		861	+9 −8	47	
Mean	0.145	0.122	103.3		86.1			
Standard deviation					2.3			
Standard error of mean					0.7			
Standard error of mean, percent					0.81			

Tested by H.B.R. Calc. by O.J.M. Checked by A.F.L.

Date 3/23/34 Date 3/28/34 Date 3/30/34

FIG. 9.—Facsimile of Record Form Used for Recording the Corrected Circumference and Machine Break and for Calculating the Strength and Variability of Strength per Square Inch.

Calculation

25. (*a*) The corrected circumference shall be calculated by obtaining the difference in the two scale readings, dividing this result by ten, and then subtracting 0.023 in. (correction for thread diameter). (See Fig. 9.)

(*b*) Each machine break shall be corrected to a bundle of standard size (0.125-in. circumference) by recourse to the accompanying Table I. The proper column to use in Table I is determined by calculating the average of the ten machine breaks and the average of their corresponding circumferences and adding or subtracting 1 lb. for each deviation of 0.001 in. according as the average size is smaller or larger, respectively, than standard. If the average circumference deviates more than 0.001 in. from the standard, a second approximation shall be made.

(*c*) The strength per square inch of each bundle shall be obtained by dividing the corrected machine break by the cross-sectional area (0.0012434 sq. in.) of a bundle of standard size. (This may be conveniently obtained by reference to a prepared table or chart.)

(*d*) The strength of a sample shall be the average strength per square inch as obtained from ten successful breaks.

TENTATIVE METHODS FOR THE IDENTIFICATION OF FIBERS IN TEXTILES AND FOR THE QUANTITATIVE ANALYSIS OF TEXTILES[1]

A.S.T.M. Designation: D 276 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1927; REVISED, 1929, 1930, 1931, 1933, 1935.

METHODS FOR THE IDENTIFICATION OF FIBERS IN TEXTILES[2]

Successful identification of the fibers used in textiles depends upon experience and familiarity with the fibers. The ultimate test of the diagnosis of an unknown is comparison with a known standard sample. It is not only desirable but necessary for the analyst to have authentic samples of the fibers likely to occur in the textiles he is called upon to analyze.

The key used in these methods is not concerned with describing the fiber but rather with pointing out for each group of fibers and finally, within the group, for each fiber, that particular characteristic or group of characteristics by which the fiber differs from similar fibers. Often this is a minor detail of structure, or staining reaction. Occasionally, it is somewhat subjective, but an effort has been made to choose objective characteristics which will be evident to all observers. For the benefit of those unfamiliar with the use of a key it should be said that the arrangement is necessarily artificial. Groups are established on the basis of similarity and dissimilarity for convenience only, and without regard for chemical, biological or industrial relationships.

The "keying out" of an unknown is simply a matter of elimination. In every division and subdivision of the key there are *two alternatives* both numbered or lettered alike. It is necessary to *reject* one and to *accept* the other as descriptive of the fiber in question. It is quite possible that neither phrase exactly describes the fiber, but it is necessary to make the best choice between the two and to follow through the entire key, step by step, in the same manner. A decision should never be made as to which group the fiber belongs until both descriptions under that designation have been considered. Except where definitely stated, descriptions are of ultimate fibers rather than of "technical" fibers or fiber aggregates. For adequate study of these a microscope is necessary, and for analytical purposes a magnification of 100 diameters is most satisfactory.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Attention is called to the Photomicrographs of Common Textile Fibers appearing in Appendix I, of the volume of "A.S.T.M. Standards on Textile Materials," p. 188; available as a separate publication, October, 1935. Photomicrographs of Rayon Fibers appear on pp. 1243 to 1247.

The technique of mounting fibers for microscopical examination is relatively simple, but experience brings proficiency and speed. To remove dyes, natural or applied oils, starch, sizing, and other materials it is advisable to begin by heating the fibers in a dilute solution of caustic soda (0.5 per cent). Because wool and hair are quickly disintegrated in hot caustic, care shall be taken to shorten the cooking in such cases. In examining fabrics this step is often not necessary. In vegetable fibers prolonged boiling is beneficial in breaking up the fiber bundles and larger aggregates so that the ultimate cells can be separated. Since most stains are indicators, it is necessary that all caustic be washed from the sample before proceeding further with the tests. Rubbing and squeezing between the fingers under running tap water is sufficient. Small samples of the fiber shall be placed on a slide and teased apart with needles. Too much material on one slide renders adequate separation difficult. It cannot be too strongly emphasized that a just and impartial consideration of the material must be based on single fibers and their minute configurations rather than on a confused mass of fibers. Moreover, several small samples taken at random from various regions of the material give more representative results than a single sample. Most stains take better if excess moisture has been blotted from the fiber with filter paper. To be sure that all fibers are stained equally they shall be stirred on the slide with needles. The most satisfactory examination of stained fibers is by transmitted light. Constant adjustment of the focus discloses the lumen and other structural features which may otherwise escape notice; and decreasing the intensity of the light by means of diaphragm or condenser adjustment is sometimes a revealing manipulation. It is worth while to notice extraneous materials which occur with the fiber. The presence or absence of epidermal cells, spirals, hairs, unusual configurations in cell groups or fiber bundles is often a clue when other features are less distinct than usual. An experienced fiber analyst has always in mind certain associations which though of no technical value, are to him, personally, dependable means of identification.

REAGENTS

The following reagents will be required:

Aniline Sulfate

Aniline sulfate	1 g.
Distilled water	100 ml.
Sulfuric acid (10 per cent solution)	1 ml.

Hemp stains yellow; linen is unstained.

Diphenylamine Solution

Concentrated H_2SO_4	20 ml.
Glacial acetic acid	10 ml.
Diphenylamine	0.3 g.

Hahn's Solution

Solution A:

Picric acid	1 g.
Distilled water	100 ml.

Solution B:

Soluble Blue 2B Extra (Color index 707)	0.2 g.
Eosin (Color index 768)	0.1 g.
Tannic acid	1.0 g.
Distilled water	100 ml.
Hydrochloric acid (10 per cent solution)	0.2 ml. (when solution has cooled)

Mix solutions *A* and *B* in equal parts for rayon tests.

Herzberg's Solution

Solution A:

Zinc chloride	50 g.
Distilled water	25 ml.

Specific gravity at 28 C. should be 1.8

Solution B:

Potassium iodide	5.25 g.
Iodine	0.25 g.
Distilled water	12.5 ml.

Add solution *B* to solution *A*, stir; let stand overnight; decant from sediment; add a leaf of iodine; keep in dark bottle.

A good general stain for all fibers. Linen, cotton, hemp, ramie are stained red; jute, phormium, sisal and other lignified fibers, yellow. De-lignified fibers and cellulose cells are stained blue.

Herzog's Cyanin

Saturated alcoholic solution of Cyanin Blue (Color Index 288)	80 ml.
Distilled water	10 ml.
Concentrated glycerine	30 ml.

Apply hot to fibers; mount fibers in concentrated glycerine. Flax fibers are unstained; hemp fibers are blue.

Millon's Reagent

Dissolve mercury in an equal weight of cold fuming HNO_3 (sp. gr. 1.4), then apply moderate heat.

Dilute solution with 2 volumes of water.

Picric Acid

Picric acid	1 g.
Distilled water	100 ml.
Sodium hydroxide	0.5 g.

Brings out surface scales on animal fibers, especially wool and mohair.

ABRIDGED KEY FOR COMMON FIBERS

The fibers commonly met in textile fabrics are cotton, linen, jute, rayon, silk and wool. A few simple tests will identify these, but it is advisable to confirm the diagnosis by other tests rather than to rely on one identification only.

A. As a preliminary test, burn a few individual fibers by applying a flame to their ends.

- Odor of burned feathers or hair; knob forms on end of fiber.................................*Silk or Wool* (see *a*).
- Odor of burned feathers or hair; ash retains shape of thread.................................*Weighted Silk* (see *a*).
- Distinctly aromatic odor, somewhat acrid; knob forms on end of thread......................*Acetate Rayon* (see *b* and *c*).
- Odor of burned paper or straw; ash shapeless; drops off.................................*Other Rayons, Cotton, Linen or Jute.*

B. Immerse fibers in an aqueous solution of caustic soda (0.5 per cent) and bring the solution to a boil. Wash thoroughly by squeezing and rubbing between the fingers under running tap water. Tease the fibers apart on a slide, blot off water with filter paper. Stain with a few drops of Herzberg's solution. Examine under magnification of 100 diameters.

- 1. Fibers yellow, white or greenish........................2.
  - 2. Fibers distinctly pointed at ends, with narrow lumen; bright golden yellow............................*Jute.*
  - 2. Fibers of indeterminate length, with cut ends.........3.
    - 3. Fibers fine, sometimes flattish, of varying diameters, transparent, without cellular structure.........4.
      - 4. Fibers with longitudinal striations, and sometimes with paired parallel lines in a diagonal direction (imprint of one fiber across another)...*Wild* (*Tussah*) *Silk* (see *a*).
      - 4. Fibers with fine diameters, without markings....*Cultivated Silk* (see *a*).
    - 3. Fibers larger, rod-shaped, with prominent scales....*Wool* (see *a* and *d*).
- 1. Fibers reddish or purple...............................5.
  - 5. Fibers cylindrical, pointed at ends, with cross marks on surface; swollen nodes, and narrow lumen.........................*Linen* (see *e*).
  - 5. Fibers lacking above characteristics..........6.
    - 6. Fibers flat, more or less ribbon-like, frequently twisted, with broad lumen....*Cotton* (see *e*).
    - 6. Fibers without any lumen, straight........*Rayon* 7.
      - 7. Fibers with distinct longitudinal striations on the surface...............*Viscose.*
      - 7. Fibers without striations...............8.
        - 8. Stain with Hahn's solution. Fibers pink..........................*Nitrocellulose Rayon* (see *f*).
        - 8. Fibers not pink....................9.
          - 9. Fibers yellow...................*Cellulose Acetate Rayon* (see *b* and *c*).
          - 9. Fibers blue or colorless...........*Cuprammonium Rayon* (see *g*).

(*a*) Millon's reagent colors true silk fibers (or other animal fibers such as wool, mohair or fur) pink. Vegetable fibers are not stained.

(*b*) Cellulose acetate rayon is dissolved in acetone; other fibers are not affected.

(*c*) Cellulose acetate rayon is dyed yellow in picric acid; other rayons wash out white.

(*d*) Surface markings, scales, etc., on wool fibers become more pronounced when fibers are stained with 1 per cent picric acid containing sodium hydroxide.

(*e*) Untwist the thread until a single dry fiber is exposed. Moisten the tip between thumb and finger; observe with a hand lens, as follows:

Fiber tip curls clockwise........................linen.
Fiber tip curls counter-clockwise................cotton.

(*f*) Nitrocellulose rayon dissolves to give a deep blue coloration when tested dry with a solution of diphenylamine in sulfuric acid.

(*g*) Cuprammonium rayon is dyed deep orange in 0.2 per cent solution of Erie Fast Orange C. G. (Color index 621); other rayons are white or weak orange.

ANALYTICAL KEY FOR IDENTIFICATION OF FIBERS

Touch end of fiber to a flame:

Fiber does not burn..........................Mineral Origin I.
Fiber burns with characteristic odor of burning feathers or glue..................................Animal Origin II.
Fiber burns with characteristic odor of burning paper or straw...............................Vegetable Origin III.

I. Fibers of Mineral Origin:

Asbestos, confirm by microscopical examination.

II. Fibers of Animal Origin:

1. Fibers coarse, more or less shiny, wiry; usually found in brushes or upholstery..............................2.
2. Fibers with diameters tapering from base to tip.......*Bristles* 3.
3. Bristles dark, with pronounced white band short distance back of tip; tips not flagged..........*Badger Bristle.*
3. Bristles same color throughout, with a knob frequently visible at butt ends where hair was pulled from follicle; tips flagged..............*Hog Bristle* 4.
4. Bristles hardly more than 1$\frac{1}{2}$ in. in length; varicolored; frequently curved; irregular as to length and diameter......................*Domestic Hog Bristle.*
4. Bristles longer than 1$\frac{1}{2}$ in., of rather uniform length, *straight*..........................5.
5. Bristles all white, or chalk white.............*Bleached "(French)" Bristle.*
5. Bristles black, yellow, or grey (black and yellow mixture).......................6.
6. Bristles 4 in. or longer, stiff, coarse, much flagged, usually grey or yellow........*Russian Bristle.*
6. Bristles all black, 4 in. or shorter..........*Chinese* 7.

7. Bristles black, rather soft, often with flagged end clipped off.............*Chungking Bristle.*
7. Bristles with flagged ends never clipped.8.
    8. Bristles very fine, soft, usually not over 3 in.....................*Tientsin Bristle.*
    8. Bristle not so fine, longer............*Hankow Bristle.*

2. Fibers with rather regular diameters throughout; little or no taper; tips not flagged; hair follicle knobs seldom present......................................*Hair* 9.
    9. Hairs wiry, all black..............................10.
        10. Hairs of average diameter of not less than 0.0055 in. (based on microscopical measurement of at least 100 hairs)............................*Horsetail Hair.*
        10. Hairs of average diameter less than 0.0055 in......*Horse Mane Hair.*
    9. Hairs usually white, yellow or brown.................11.
        11. Hairs smooth, scales scarcely visible..........12.
            12. Hairs, smooth, roundish, showing under magnification of 100, distinct pigmentation, not isolated in a medulla, but scattered in lumpy streaks...........*Horsehair* (see 10).
            12. Hairs less smooth, exhibiting less "character" than the above; showing under magnification of 100, distinct medulla with pigment closely packed in flat, accordion-like masses................*Cattle Hair.*
        11. Hairs coarse with prominent, surface scales, wide medulla filled with pigment but not packed in any characteristic arrangement........*Goat Hair*

1. Fibers fine, soft, more or less silky; from soft brushes, or from felts and fabrics.............................13.
    13. Fibers fur-like.............................14.
        14. Fibers showing pigmentation in wide medulla with regularly spaced blocks of pigment (×100)..................15.
            15. Hairs rather short, with pigment blocks in 1 or 2 rows..................*Common Rabbit.*
            15. Hairs abnormally long, showing more than 2 rows of pigment blocks....*Angora Rabbit.*
        14. Fibers showing pigment tightly packed in wide medulla, in irregularly checked mass..............................*Squirrel.*
    13. Fibers filamentous 16.
        16. Fibers rod-shaped with medullary canals, and scaly surfaces (×100)...17.
            17. Fibers tan, brown or black........18.
                18. Fibers with distinctly granular pigmentation and indistinct hollow medulla......*Alpaca.*
                18. Fibers with no distinct medulla except in kemps where medulla is large and heavily pigmented...........*Camel Hair.*

17. Fibers usually white........................19.
19. Fibers with fine scales closely appressed to fiber surface; diameter usually small..*Mohair.*[1]
19. Fibers of various diameters, scales coarser, more loosely arranged..............*Wool.*
16. Fibers flat, smooth, transparent, void of cellular structure..................................20.
20. Fibers broad, varying in diameter, marked with longitudinal striations, and frequently with parallel diagonal lines where one fiber crossed over another has left an impression......................*Wild* (*Tussah*) *Silk.*
20. Fibers single, narrow, without striations.........................*Cultivated Silk.*

III. Fibers of Vegetable Origin:

For convenience these are grouped according to their uses as: *A. Brush Fibers, B. Cordage Fibers,* and *C. Vegetable Fibers from Fabrics.*

A. Brush Fibers[2]

1. Fibers hair-like, or rope-like, white, yellow (or dyed).....*Tampico.*[3]
1. Fibers more woody than hair-like......................2.
2. Fibers dark brown or black..........................3.
3. Fibers thick, more or less circular, corky in texture..*Rattan.*
3. Fibers not corky, but woody....................4.
4. Fibers thin, wiry, circular....................*Bassine.*
4. Fibers thicker, flatter, more woody, brittle.......*Bass.*
2. Fibers reddish, wiry...............................*Palmetto.*

B. Cordage Fibers

Apply Swett's test as follows:

Wash sample in alcohol to remove grease. Immerse in nascent chlorine solution for 30 sec. Wash in tap water; rinse in alcohol to remove water. Hold over concentrated ammonium hydroxide. Fumes produce:

Cherry red color ....Sisal and other rope fibers.
Brown color............................Manila fibers.

1. Fibers brown or yellow.............................*Abaca* (Manila).[4]

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[1] Scales may be brought out distinctly by staining with picric acid.

[2] The term "fiber" is here used in its technical sense, meaning not the ultimate fiber cell, but rather a bundle or an aggregate of fibers.

[3] Sisal, palma, istle, henequen and other agaves.

[4] Confirm by microscopical examination for broad lumen.

1. Fibers cherry red or pink.............................2.
  2. Treat fibers in boiling dilute caustic, wash, separate into ultimate cells; stain with Herzberg's solution, examine under magnification of 100. Fibers yellow.............................3.
    3. Fibers more or less rounded at ends, diameters regular, fiber surface strikingly smooth, canal not visible; fiber bundles usually accompanied by spirals.............................(*Phormium Tenax*).
    3. Fibers distinctly pointed at ends, with irregular diameters, thick cell wall, and distinct narrow lumen.............................4.
      4. Fiber bundles accompanied by spirals and epidermal cells.............................*Agave* (Sisal, Hene- quen, etc.).
      4. Fiber bundles free from spirals. Characteristic surface markings on fiber.........*Jute.*
  2. Fibers red, purple or blue.............................5.
      5. Fibers ribbon-like, flat, twisted, with broad lumen.............................*Cotton.*
      5. Fibers not twisted; lumen narrow; bumps, swellings, cross striations on fiber surface. Red fibers frequently accompanied by yellow epidermal cells (shive)............6.
        6. Stain with Herzog's cyanin (or with Aniline sulfate). Fibers stained.............7.
          7. Stain with Herzberg's solution: Yellow epidermal cells with prominent hook hairs near stomatal openings.......*Sunn Hemp.*
          7. Yellow epidermal cells devoid of hairs...*True Hemp.*
        6. Stained with Herzog's cyanin. Fibers colorless.............................*Flax.*

C. Vegetable Fibers from Fabrics

(Or used in Battings, Cushion Filling, etc.).

1. Fibers silky in appearance, with shiny surface...........2.
  2. Fibers short, very fine, downy; examined under microscope showing broad lumen, air filled; very thin cell wall.............................*Kapok.*
  2. Fibers of indeterminate length; threadlike............3.
    3. Dip for 3 minutes in Hahn's stain, wash in cold water. Fibers pink.............................4.
      4. Fibers deep pink.............................*Nitrocellulose Silk.*[1]
      4. Fibers pale pink.............................*Viscose Silk.*[2]
    3. Fibers not pink.............................5.
      5. Fibers yellow.............................*Acetate Silk.*[3]
      5. Fibers blue.............................*Cuprammonium Silk.*

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[1] Confirm by test with diphenylamine—sulfuric acid for blue color.

[2] Confirm by microscopical examination for striated surfaces.

[3] Confirm by dissolving in acetone.

1. Fibers not silky....................................6.
    - 6. Stain with Herzberg's solution, examine microscopically. Fibers yellow...............*Jute.*
    - 6. Fibers red or purple.........................7.
        - 7. Fibers with narrow lumen, swollen nodes, distinct cross markings...............8.
            - 8. Moisten tip of single fiber between thumb and finger: Fiber curls clockwise..................*Linen.*
            - 8. Fiber curls counter-clockwise...........*Hemp.*
        - 7. Fibers with broad lumen.................9.
            - 9. Fibers broad, flat, with unusually wide diameter; joints and transverse fissures prominent..............*Ramie.*
            - 9. Fibers not broad and flat; diameters more or less uniform............*Cotton* 10.
                - 10. Fibers ribbon-like, twisted.......*Raw Cotton.*
                - 10. Fibers swollen, round, with partially destroyed lumen......*Mercerized Cotton.*

METHODS FOR THE QUANTITATIVE ANALYSIS OF TEXTILES

Scope

1. These methods provide for the quantitative determination of the water, total non-fibrous materials, cellulose acetate rayon, silk, regenerated cellulose rayon, cotton, and wool present in textiles composed of two or more of these materials. Any section of the methods which is not applicable in a particular analysis may be omitted. It is assumed that the analyst knows from qualitative tests what materials are present. All results shall be based upon the weight of the dried material.

Water or Regain

2. (*a*) Unless otherwise specified, samples to be analyzed for water shall be conditioned by exposure to an atmosphere having a relative humidity of 63 to 67 per cent and a temperature of 70 to 80 F. (approximately 21 to 26 C.) until equilibrium is established. The material shall be considered to be in equilibrium when it shows no progressive change in weight.

(*b*) The special equipment for drying specimens to constant weight which is generally available in textile laboratories may be used. The procedure outlined in Paragraphs (*c*) to (*f*) is provided for laboratories not so equipped and shall be used in the settlement of disputes unless some other method is agreed upon by those concerned.

(*c*) A glass weighing bottle of approximately 100-ml. capacity fitted with a ground-glass cover shall be dried at 220 to 230 F. (105 to 110 C.) to constant weight. A satisfactory procedure is to place the bottle and cover separately in the oven. After drying for 1 hr. they shall be transferred to a desiccator and allowed to cool to room temperature. The cover shall then be placed on the bottle which shall then be weighed. The heating, cooling and weighing shall be repeated until the weight is constant to within ± 0.003 g. This is the "weight of weighing bottle." The weighing bottle shall be kept in a desiccator when not in use.

(*d*) A specimen of approximately 5 g. of the material to be tested shall be placed in the weighing bottle which shall then be covered and weighed. By subtracting the "weight of weighing bottle" (Paragraph (*c*)) from this weight, the weight of specimen, A, is obtained.

(*e*) The specimen shall be removed from the weighing bottle, placed on a watch glass in the oven (temperature 220 to 230 F. (105 to 110 C.) as before), and dried for 1.5 hr., then quickly transferred to the weighing bottle, which shall be placed uncovered in a desiccator. When the specimen and bottle have cooled to room temperature, the cover shall be replaced on the bottle which shall then be weighed. The specimen shall be returned to the oven and the drying, cooling and weighing shall be repeated until the weight is constant to within ±0.003 g. By subtracting the "weight of weighing bottle" (Paragraph (*c*)) from this weight, the weight of dry specimen, B, is obtained.

(*f*) *Calculation.*—The water content shall be calculated from the following formula:

$$\text{Water content of specimen (dry basis) or regain, per cent} = \frac{A - B}{B} \times 100$$

where A = the weight of specimen; and
B = the weight of dry specimen.

Total Sizing, Finishing and Other Non-Fibrous Materials

3. (*a*) The purpose of this procedure is to remove all non-fibrous natural constituents of the fiber and substances added by the manufacturer. Starch, China clay, soaps, some waxes, some non-drying oils and the usual natural constituents are in this category and are removed by the procedure given. However, general directions for the removal of all possible substances which may be present cannot be given. The delustered rayons and some of the newer finishes present special problems. The analyst will have to meet special cases as they arise. When it is necessary to modify the procedure in

order to completely remove non-fibrous constituents, the analyst shall make sure that purified samples of the fibers under consideration do not lose weight when subjected to the same treatment. Ordinarily, samples shall be analyzed in accordance with Paragraphs (*b*) to (*d*).

(*b*) A specimen of approximately 5 g. shall be taken for test. Particular care shall be taken to prevent the loss of fibers in the treatments. The specimen shall be dried at 220 to 230 F. (105 to 110 C.) to constant weight (Section 2 (*e*)). This gives the weight of dry specimen, *B*.

(*c*) The specimen shall then be extracted for 2 hr. with carbon tetrachloride in a Soxhlet or similar extractor. The specimen shall be allowed to dry in the air. It shall then be washed by repeated immersion in hot distilled water, squeezing between each immersion.

(*d*) The specimen shall then be immersed in a 3 to 5 per cent aqueous solution of a starch and protein-solubilizing enzyme preparation at 122 F. (50 C.). It shall be squeezed while immersed, removed and squeezed again, and this procedure repeated at least three times. The purpose is to insure thorough wetting of the fibers by the enzyme solution. The enzyme solution shall then be maintained at 122 to 140 F. (50 to 60 C.), or the optimum temperature range for the particular enzyme used, and the specimen kept immersed in it for 1 hr. A shorter time is permissible if sizing is removed in the shorter time. Fifteen minutes is sufficient for some textiles. The specimen shall then be rinsed twelve times in fresh portions of hot distilled water, squeezing after each rinse. Thorough rinsing is necessary in order to remove china clay from heavily filled fabrics. The enzyme treatment and rinsing may be carried out in a Launder-Ometer or similar device if desired. The rinsed specimen shall then be dried at 220 to 230 F. (105 to 110 C.) to constant weight. This gives the weight of dry fiber, weight *C*.

(*e*) *Calculation.*—The total amount of non-fibrous constituents present shall be calculated from the following formula:

$$\text{Total sizing, finishing and other non-fibrous materials (dry basis), per cent} = \frac{B - C}{B} \times 100$$

where B = the weight of dry specimen (Paragraph (*b*)); and
C = the weight of dry fiber (Paragraph (*d*)).

Cellulose Acetate Rayon

(Acetone Soluble Types Only)

4. (*a*) The specimen after being tested in accordance with Section 3 shall be agitated vigorously for 15 minutes in about 50

times its weight of acetone at room temperature.[1] The residue shall be rinsed while squeezing by alternate immersion in acetone, two fresh portions of acetone being used. The residue shall be allowed to dry and them immersed in water at a temperature of about 158 F. (70 C.). The excess water shall be removed by squeezing and the residue dried to constant weight as described in Section 2 (*e*). This weight is called *D*.

(*b*) *Calculation.*—The cellulose acetate rayon content shall be calculated from the following formula:

$$\text{Cellulose acetate rayon (dry basis), per cent} = \frac{C - D}{B} \times 100$$

where B = the weight of dry specimen (Section 3 (*b*));
C = the weight of dry fiber (Section 3 (*d*)); and
D = the weight of dry specimen after cellulose acetate rayon test.

Silk

5. (*a*) The fibers constituting the residue from the test for cellulose-acetate rayon (Section 4) shall be cut to lengths of about 2 to 4 mm. They shall be agitated vigorously for 1 hr. in 200 ml. of a clear aqueous solution of calcium thiocyanate of specific gravity 1.20 to 1.21 at a temperature of 158 F. (70 C.) made just acid to litmus with acetic acid, and maintained at a temperature of 158 ± 4 F. (70 ± 2.2 C.). Precautions shall be taken to prevent evaporation from the solution with consequent concentration of the thiocyanate. The fibers which are not dissolved shall be collected in a small Büchner funnel, Gooch crucible, or bitumen filter, preferably with the aid of suction. When a good pad of fibers has formed on the filter, the hot mother liquor shall be poured through a second time to recover all fibers on the pad. The fibers shall then be agitated for 5 min. in a fresh 200-ml. portion of the thiocyanate solution. The filtration shall be repeated and the fibers washed with hot distilled water until free from thiocyanate. They shall be dried to constant weight, weight *E*.

(*b*) *Calculation.*—The silk content shall be calculated from the following formula:

$$\text{Silk (dry basis), per cent} = \frac{D - E}{B} \times 100$$

where B = the weight of dry specimen (Section 3 (*b*));
D = the weight of dry specimen (Section 4 (*a*)); and
E = the weight of dry specimen after silk test.

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[1] A Launder-Ometer can be used to obtain satisfactory agitation.

Regenerated Cellulose Rayon

6. (*a*) The fibrous residue from the test for silk (Section 5) shall be pulled apart or cut up. It shall be treated in accordance with the procedure in Section 5 except that the acid solution of calcium thiocyanate shall be of specific gravity 1.35 to 1.36 at a temperature of 158 F. (70 C.). The weight of the dried residue from this treatment is weight *F*.

(*b*) *Calculation.*—The regenerated cellulose rayon content shall be calculated from the following formula:

$$\text{Regenerated cellulose rayon (dry basis), per cent} = \frac{E - F}{B} \times 100$$

where B = the weight of dry specimen (Section 3 (*b*));
E = the weight of dry specimen after the silk test (Section 5 (*a*));
F = the weight of the dried residue.

Cotton

7. (*a*) The residue from the test for regenerated cellulose rayon (Section 6), which contains cotton and wool, shall be immersed for 10 minutes in a boiling solution of aluminum chloride containing 5 g. of $AlCl_3$ (or 9 g. of the hydrated salt $AlCl_3 \cdot 6H_2O$) per 100 ml. of water. It shall be removed from the solution and after allowing the excess liquid to drain off (the specimen shall not be squeezed), it shall be heated in an oven at 221 to 230 F. (105 to 110 C.) until the cotton has become brown in color and brittle (usually 2 hr. is sufficient). The specimen shall be placed on a 100-mesh screen and rubbed against the screen with sufficient pressure to powder the carbonized cellulose and pass it through. The residual fibers (wool) shall be placed in a suitable container, preferably a 250-ml. beaker. The material which passed through the screen shall be screened again to recover any wool fibers which passed through. The wool shall be agitated with about 100 ml. of dilute hydrochloric acid solution (1 part by volume of the concentrated laboratory reagent diluted with 9 parts of distilled water), collected as a pad (see Section 5 (*a*)), washed with distilled water until free from chlorides, and dried at 221 to 230 F. (105 to 110 C.) to constant weight, weight *G*.

(*b*) *Calculation.*—The cotton content shall be calculated from the following formula:

$$\text{Cotton (dry basis), per cent} = \frac{F - G}{B} \times 100$$

where B = the weight of dry specimen (Section 3 (*b*));
F = the weight of the dried residue (Section 6 (*a*)); and
G = the weight of the dry specimen after the cotton test.

Wool

8. The wool content of the specimen shall be calculated from the following formula:

$$\text{Wool (dry basis), per cent} = \frac{G}{B} \times 100$$

where B = the weight of dry specimen (Section 3 (b)); and
G = the weight of the dry specimen after the cotton test.

TENTATIVE METHODS OF TESTING PILE FLOOR COVERING[1]

A.S.T.M. Designation: D 418 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These methods of testing are intended to be applicable for testing pile floor coverings.

Sampling

NOTE.—The size of dissection samples and methods of sampling will be covered in later revisions of these methods.

Condition

2. (*a*) *Unconditioned*.—The weight of the fabric when samples for weight determination are cut from it is the unconditioned weight. A specification of the weight of a fabric must also specify the moisture condition.

(*b*) *Oven-Dry Condition*.—The oven-dry condition of pile fabrics is that state of dryness obtained on equilibrium of the material in a ventilated drying oven maintained at a temperature of 220 to 230 F. (105 to 110 C.).

(*c*) *Standard Condition*.—Standard condition of pile fabric is that reached by the fabric in equilibrium with an atmosphere having a relative humidity of 65 per cent ± 2 per cent at 70 to 80 F. (21 to 27 C.).

(*d*) *Moisture Equilibrium*.—It shall be considered that moisture equilibrium is reached when two successive weighings not less than 30 min. apart show not more than 1.0 per cent change in weight.

Test Condition

3. All fabrics shall be tested under standard conditions as described in Section 2 (*c*).

QUANTITY

Length

4. The length of a roll or piece shall be determined by running the fabric over a measuring drum of known circumference, from which the yardage is registered by a dial or a counter driven by a chain, or other positive non-slip mechanism. This yardage shall be the length of the fabric and shall be independent of any effect of its thickness.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.

Width

5. (*a*) The width of a roll or piece shall be determined at five different places uniformly distributed along the full length of the roll or piece, and may be determined at the same time as the total length.

(*b*) Measurements shall be made to the nearest $\frac{1}{16}$ in.

(*c*) The average of five measurements shall be the width.

Weight

6. (*a*) *Unconditioned Weight.*—Samples in a condition which is the same as the fabric they represent shall be rapidly weighed on a balance sensitive to 0.1 per cent of the total weight. The average of these weights shall be the unconditioned weight of the samples.

(*b*) *Conditioned Weight.*—The samples shall be allowed to come to standard condition as described in Section 2 (*c*). The average of the samples weighed under standard conditions shall be the conditioned weight of the samples and shall be used to calculate the conditioned weight of the fabric.

(*c*) *Oven-Dry Weight.*—One of the samples shall then be converted to the oven-dry condition as described in Section 2 (*b*). This shall be the oven-dry weight of the sample.

Moisture Content and Regain

7. (*a*) *Weight of Moisture.*—The difference between the unconditioned weight (Section 6 (*a*)) and the oven-dry weight (Section 6 (*c*)) shall be the weight of moisture present.

(*b*) *Moisture Content.*—The weight of moisture when calculated as a percentage of the unconditioned weight shall be the "moisture content" of the fabric.

(*c*) *Moisture Regain.*—The weight of moisture when calculated as a percentage of the oven-dry weight shall be the "moisture regain" of the fabric.

Total Thickness

8. Thickness of a fabric shall be determined by measuring to the nearest 0.001 in. the distance between the two plane surfaces of a fabric under a pressure of 0.100 ± 0.001 lb. per sq. in. distributed over a circular area 3.00 in. ± 0.01 in. in diameter. The pressure shall be applied slowly to avoid impact, and the fabric shall be protected from vibration during test. The average of five readings taken at different places, uniformly distributed over the area of the surface, shall be the thickness.

CONSTRUCTION

Back Thickness

9. A section of fabric shall be singed so as to remove the pile yarn without damaging the back construction. The thickness of the remaining

back construction in four places shall be determined using the same pressure as in Section 8. The average of four tests shall be the back thickness.

Net Pile Height

10. The net pile height is the difference between the total thickness and the back thickness, as determined in Sections 8 and 9.

Rows

11. The number of rows of tufts per inch shall be determined by counting a space of not less than 10 in. in at least three different places. No two count determinations shall include the same rows. The row count of the fabric shall be the average of the number of rows per inch in these three tests.

Pitch

12. The number of pile ends per inch of width shall be determined by counting the tufts in a space of not less than 10 in. in at least three different places staggered across the piece. The pitch of the fabric shall be the average of the number of pile ends per inch found in these three tests.

Shot

13. The number of shots in a single repeat of the weaving cycle, or the number of travels of filling yarn per row of tufts, shall be noted. This number shall be the shot of the fabric. In Axminster weaves or fabrics woven on a needle loom, the double thread or filling left by one movement of the needle shall be considered as one shot.

Dissection

14. Samples, in standard condition and which have not been oven-dried, shall be completely picked apart dividing the yarn according to its utility in the carpet, that is pile, warp, stuffer and filling. The debris from the dissection shall be included in the pile yarn weight.

Weights

15. (*a*) The yarns sorted according to their construction purpose shall be weighed under standard conditions.

(*b*) *Pile Yarn.*—The average of the weights of the samples of pile yarn shall be the conditioned weight of pile yarn.

(*c*) *Clean Pile Yarn.*—The average of the weights of the samples of pile yarn, after extraction to remove fats and after desizing to remove sizing materials, shall be the conditioned weight of clean pile yarn.

(*d*) *Warp Yarn.*—The average of the weights of the samples of warp yarn shall be the conditioned weight of warp yarn.

(*e*) *Stuffer Yarn.*—The average of the weights of the samples of stuffer yarn shall be the conditioned weight of stuffer yarn.

(*f*) *Filling Yarn.*—The average of the weights of the samples of filling yarn shall be the conditioned weight of filling yarn.

(*g*) *Weights per Square Yard.*—Each of the conditioned weights of pile, clean pile, warp, stuffer and filling yarn, determined in accordance with Paragraphs (*b*) to (*f*), shall be corrected to the weight per square yard by multiplying by the proper constant and shall be reported as the weight of pile yarn, clean pile yarn, warp yarn, stuffer yarn and filling yarn per square yard, respectively.

(*h*) *Clean Backing Yarns.*—When required, the average of the weights of the samples of warp yarn, stuffer yarn and filling yarn after extractions to remove fats and after desizing to remove size, shall be the conditioned weight of clean warp yarn, clean stuffer yarn and clean filling yarn, respectively.

NOTE.—Methods for desizing and fat removal will be developed and added later.

TENTATIVE METHODS OF TESTING AND TOLERANCES
FOR
RAYON[1]

A.S.T.M. Designation: D 258 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1926; REVISED, 1927, 1931, 1932, 1935.

Scope

1. These methods of testing and tolerances apply to the various types of rayon in the form of filaments or yarn.

DEFINITIONS

Rayon

2. (*a*) *Rayon.*—A generic term for filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice, and solidifying it in the form of a filament.

NOTE.—Rayon as commercially manufactured is produced by four different processes. The resulting rayons from each process while similar in appearance differ among themselves and with each other to a more or less degree according to the differences in their physical and chemical properties. The different type rayons, as defined in these specifications, are known as follows:

(*a*) Nitrocellulose Rayon (Chardonnet)
(*b*) Viscose Rayon
(*c*) Cuprammonium Rayon
(*d*) Cellulose-Acetate Rayon

(*b*) *Rayon Yarns.*—Yarn composed of more than one continuous rayon filament.

(*c*) *Spun Rayon.*—Yarn made from cut rayon filaments, the cut filaments being drawn out and twisted into a yarn by usual spinning processes, as follows:

(*1*) Cotton system of spinning (ring and mule).
(*2*) Worsted system of spinning (modified Bradford) (cap or ring).
(*3*) Spun-silk method of spinning (ring or mule).

Classification

3. (*a*) *Nitrocellulose Rayon.*—Filaments composed of a regenerated or denitrated cellulose which has been coagulated or solidified from a solution of nitrated cellulose.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

(*b*) *Viscose Rayon.*—Filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose xanthate.

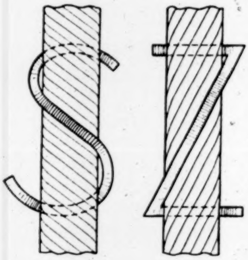
(*c*) *Cuprammonium Rayon.*—Filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose in ammoniacal copper oxide.

(*d*) *Cellulose-Acetate Rayon.*—Filaments composed of an acetic ester of cellulose which has been coagulated or solidified from its solution.

Direction of Twist

4. The direction of twist shall be as defined in the Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 35 T) of the American Society for Testing Materials, as follows:

Twist, Direction of.—A yarn or cord has "S" twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and "Z" twist if the spirals conform in slope to the central portion of the letter "Z."



"S" Twist "Z" Twist

Denier (Rayon Yarn)

5. The denier of a rayon yarn is the weight in grams of 9000 meters.

Number (Spun Rayon Yarn)

6. Spun rayon yarns are numbered on the basis of the system by which they are spun.

TOLERANCES

Tolerances

7. Tolerances shall be the limits within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract.

Denier of Rayon Yarn

8. (*a*) The average denier of the rayon yarn, either bleached or unbleached, in each skein, tube, spool, cop, pirn, or cone of rayon as supplied by the seller, as found by test, shall not vary above or below the specified denier more than:

10 per cent for denier finer than 150, and
8 per cent for 150 denier or coarser.

(*b*) The average denier of the rayon yarn in the singles, either bleached or unbleached, in each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp as found by test shall not vary above or below the specified denier more than:

5 per cent for denier finer than 150, and
4 per cent for 150 denier or coarser.

Number of Spun Rayon Yarn

9. The average number of the spun rayon yarn in the singles, either bleached or unbleached, in each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp, as found by test, shall not vary more than 5 per cent above or below the specified number. Spun rayon yarns are numbered on the basis of the system by which they are spun.

Tensile Strength

10. (*a*) The average tensile strength of the rayon yarn in each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp in the singles, or plied, either bleached or unbleached, as found by test, shall not be less than the specified tensile strength.

(*b*) Ultimate tensile strength, or tensile strength at the highest yield point, may be specified.

Twist

11. The average twist of the rayon yarn in each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp shall not vary beyond the following specified limits:

TURNS PER INCH	PERMISSIBLE VARIATIONS
Under 7½	± 25 per cent
7½ to 10	± 15 per cent
Over 10	± 5 per cent

METHODS OF TESTING

IDENTIFICATION

General

12. (*a*) The following procedure assumes that the rayon is known to be one of the four common types of rayon defined in Section 3. If this is not definitely known, the sample shall be examined according to the general procedure given in Tentative Methods for the Identification of Fibers in Textiles and for the Quantitative Analysis of Textiles (A.S.T.M. Designation: D 276 – 35 T) of the American Society for Testing Materials.[1]

(*b*) Three methods of identification are given, depending on physical properties, chemical properties and optical properties. In general, no one method is completely reliable, particularly when distinguishing between cuprammonium and viscose rayon.

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[1] See p. 1215.

(*c*) While not essential, it is desirable that the analyst should have available a series of authentic samples of the different types of rayon yarn. These samples should be from various sources and should be kept as nearly up to date as possible.

Preparation of Sample

13. These methods are intended for rayon which is substantially free from color imparted by dyestuffs or colored pigments either before or after spinning, is in either bleached or unbleached state (Note), and is free from oil, finish or other foreign substances. If any of the latter are present, they shall be removed from the sample by digesting successively with the following solvents:

(*a*) Distilled water at a temperature of 158 to 176 F. (70 to 80 C.) for 15 min.

(*b*) Denatured alcohol at room temperature for 5 min.

(*c*) Diethyl ether (sulfuric ether) at room temperature for 5 min.

The sample shall be wrung out after each immersion in order to remove the excess of the solvent before transferring it to the next solvent. Finally, the sample shall be allowed to dry at room temperature.

NOTE.—The procedures described herein may be applied to colored yarn, stripped or unstripped, but the results are less reliable.

Physical Tests

14. (*a*) If sufficient sample of rayon yarn is available, the denier and the filament count shall be determined. These values shall be compared with the various numbers offered for sale commercially by the different producing rayon companies. Occasionally, as in the case of very fine denier, this will definitely determine the type of rayon yarn. At other times, it merely limits the number of possibilities and, on occasion, is of no assistance.

NOTE.—This test is valuable only when the sample is known to be material of fairly recent manufacture and is known to be a commercial product, not an experimental lot.

(*b*) A few strands of the sample shall be twisted and the mass brought as close as possible to a flame without permitting it to burn. Cellulose-acetate rayon is thermoplastic and will soften or melt, depending on the temperature. In the latter case it forms a hard ball. Nitrocellulose, viscose and cuprammonium rayon do not fuse when heated.

Chemical Examination

15. (*a*) *To Identify Cellulose-Acetate Rayon:*

Treat a few strands of the sample with c.p. acetone. Cellulose-acetate rayon dissolves.

Treat a few strands of the sample with a boiling solution of acetic acid (40 g. of glacial acetic acid with 60 g. of distilled water). Cellulose-acetate rayon dissolves.

Nitrocellulose and cuprammonium and viscose rayon do not dissolve in either of the two solvents mentioned above. Partially saponified or hydrolyzed cellulose-acetate rayon partly dissolves in the solvents described above.

(*b*) *To Identify Nitrocellulose Rayon:*

If the sample is not cellulose-acetate rayon, treat a few strands with diphenylamine reagent (66 g. of concentrated sulfuric acid, 33 g. of glacial acetic acid, 1 g. of diphenylamine) (Note 1). Nitrocellulose rayon gives a blue color; cuprammonium and viscose rayon do not give a blue color (Note 2). Nitrocellulose rayon dissolves faster than cuprammonium or viscose rayon.

NOTE 1.—Diphenylbenzidine may be substituted for diphenylamine in the above reagent.

NOTE 2.—This is essentially a test for oxidizing agents and cannot be relied on in the presence of residual bleaches such as peroxide or hypochlorite. A reagent which is exposed to the air for some time will develop a blue shade in the absence of other oxidizing agents. Active reducing agents such as hydrosulfite and some dyestuffs interfere with the test.

(*c*) *To Identify Viscose Rayon:*

If the sample is not cellulose-acetate or nitrocellulose rayon, make the following sulfide test:

Place a 5-g. sample (Note 1) of the rayon to be tested in a 250-ml. Erlenmeyer flask together with 100 ml. of water and 3 ml. of concentrated sulfuric acid. Completely cover the mouth of the flask with a piece of lead acetate paper, fastening the paper securely in position and allow to stand at a temperature of 194 to 203 F. (90 to 95 C.) for 4 hr. Viscose rayon stains the lead acetate paper yellowish to brown or possibly black (Note 2). Cuprammonium rayon does not discolor the paper.

NOTE 1.—If less than 5 g. of the sample is available take a smaller sample with the same relative quantities of reagent and place them in a test tube.

NOTE 2.—This is a test for sulfides. As the methods for purifying viscose rayon become more and more efficient, samples are encountered occasionally which do not give a positive test.

(*d*) *To Identify Cuprammonium Rayon by Stain Tests:*

Four different stain tests are recommended as follows because no one stain test can be relied upon in every case:

Wright Stain Test.—Immerse an air-dry sample for a few seconds in a boiling saturated alcoholic solution of Wright stain, rinse thoroughly in cold water. Viscose rayon is stained blue; cuprammonium rayon is stained violet.

Erie Fast Orange.—Dye the sample in a 0.2 per cent solution of Erie Fast Orange CG (Color Index No. 621). Viscose rayon is white to weak orange; cuprammonium rayon is dyed deep orange.

Neocarmin W.—Immerse a small sample for 3 to 5 min. in a solution of Neocarmin W (Eimer & Amend). Rinse in running water, pass quickly through water containing a trace of ammonia, rinse well and dry. Viscose rayon is dyed violet; cuprammonium rayon is dyed blue.

Diphenyl Fast Green.—Immerse a small sample in a 1 per cent solution of Diphenyl Fast Green B (Geigy Co.) for 2 min. at 68 F. (20 C.) Add Glauber's salt. Remove, rinse and dry. Cuprammonium rayon is dyed green, viscose rayon is undyed.

NOTE.—Dye tests depend upon the nature of the surface of the rayon yarn and the subsequent treatment received in processing and finishing. While generally indicative, manufacturing processes occasionally mask the difference between these two types of rayon and it is desirable to supplement the above tests with a microscopical examination.

Cuprammonium rayon cannot be satisfactorily identified by determining residual copper.

If previous tests indicate that the sample is not viscose, acetate or nitrocellulose rayon, it may be presumed that it is cuprammonium rayon but this should be checked by physical and optical methods.

Optical Test Apparatus

16. When possible, a microscopic examination of the lateral surface and cross-section of the sample should be made, particularly in the case of cuprammonium and viscose rayon. For this purpose any good chemical microscope may be used, but examination may be made with the following equipment which represents the least amount of apparatus which will give satisfactory results:

Microscope with achromatic objectives 16 mm. and 4 mm., 10X eye piece, Abbe Condenser N. A. 120. Type Bausch & Lomb No. FFS6, Spencer Lens Co. No. 44F or equivalent.

The following accessories will be required:

A lamp with Daylite Glass, Type Bausch & Lomb No. 4597-C and 4579, or Spencer Lens Co. No. 370, or equivalent.

Microscope slide and cover glasses.

Mounting medium, either methylene iodide or monobrom naphthalene.

Optical Tests

17. (*a*) *Examination of the Lateral Surface.*—Clean the microscope slide by flaming or with solvent, place on this a few filaments from the unknown sample and add a drop of the mounting medium to the filaments on the slide. Place a cover glass over the sample and liquid, pressing them down until the mounting medium wets the whole of the underside of the cover glass. Place the slide on the microscope stage, adjust the light, and focus, using first the 16 mm. and then the 4 mm. objective with the 10X eye piece. Compare the samples with the series of standard plates appended.[1]

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[1] See the photomicrographs on pp. 1243 to 1247.

Viscose rayon can be readily distinguished from cuprammonium rayon by the many fine striations parallel with the axis of the filaments. Cuprammonium rayon is unstriated.

(*b*) *Cross-Sectional Examination.*—Prepare a thin cross-section of the sample by twisting several strands together and embedding them in wax, in a cork, or in a Schwarz sectioning plate.[1] Cut a thin section by means of a microtome or a sharp safety razor blade. Mount the sample on a microscope slide and if wax has been used, remove this by dissolving with xylene. Focus as described above and compare the image with the series of standard cross-section plates appended.[2]

Viscose rayon has an irregular serated edge, cuprammonium rayon is almost round and has a serated edge.

NOTE.—Certain types of high tenacity viscose rayon processed in strong acid baths Lilienfeld type) appear much more like cuprammonium rayon than regular viscose rayon.

YARN DENIER

Yarn Denier Determination

18. (*a*) The denier of rayon yarn shall be determined (except when the rayon is on beams, see Paragraph (*b*)) from skeins which have been prepared, reeled, and weighed under prevailing atmospheric conditions from the spools, cops, tubes, cones, skeins, or other packages.

(*b*) Rayon received on beams shall be tested as specified.

Test Skein

19. Any reel employing a straight wind traverse having a perimeter of 112.5 cm. may be used. (See Note.) For yarns in skein form, a speed of 100 to 150 r. p. m. shall be used. For yarns on spools, cops, tubes or cones, the yarn shall be drawn off over end and a speed of 200 to 300 r. p. m. of the reel shall be used. The tension on the yarn shall not be heavier than is necessary to lay the yarn smoothly on the reel at the specified speed. The skeins shall be weighed separately on a balance which shall be accurate to 0.25 per cent of the average weight of one skein.

NOTE.—In a laboratory which is equipped for testing cotton yarns only, the skeins may be prepared on any reel having a perimeter of $1\frac{1}{2}$ yd. Each skein must contain 200 turns as before.

If a skein of this length is used, the yarn denier shall be calculated from the corrected weight (Section 22) by the following formulas:

When weighing is made in grams:

$$\text{Denier} = \frac{\text{Weight of 300-yd. skein in grams} \times 1.64}{0.05 \text{ gram (per denier)}}$$

When skeins are weighed in grains:

$$\text{Denier} = \frac{\text{Weight of 300-yd. skein in grains} \times 1.64}{0.7716 \text{ grain (per denier)}}$$

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[1] Obtainable from Spencer Lens Co. or Bausch & Lomb Optical Co.

[2] See the photomicrographs on pp. 1243 to 1247.

Number of Denier Tests

20. Two skeins of 200 turns each from each of 10 spools, cops, tubes, cones or skein bundles, from one case out of every 10 cases shall be made, and the average of these 20 tests shall be the denier of the rayon yarn.

Weight Correction

21. The weight of each skein shall be reduced to a common basis of standard moisture regain for the class of rayon under test by the following formulas:

(*a*) *For nitrocellulose, viscose and cuprammonium rayons:*

$$\text{Weight, corrected to 11 per cent moisture regain} = \frac{\text{Actual skein weight} \times 111}{100 + \text{actual percentage of regain}}$$

(*b*) *For cellulose acetate rayons:*

$$\text{Weight, corrected to 6.5 per cent moisture regain} = \frac{\text{Actual skein weight} \times 106.5}{100 + \text{actual percentage of regain}}$$

Moisture Regain, Actual

22. To determine the actual percentage of moisture regain present in the test skeins (Section 19), two groups of three skeins each shall be taken immediately after weighing and the weight of each group recorded. They shall then be placed in two separate baskets in a conditioning oven and dried to constant weight on a balance sensitive to 0.25 per cent of the average weight of one skein at 220 to 230 F. (105 to 110 C.). The moisture regain of each group shall then be calculated as the percentage of the dry weight and the average of these two shall be the actual percentage of moisture regain in the skeins.

Calculation

23. The denier shall be calculated as follows:

$$\text{Denier} = \text{Corrected weight of 225-meter skein in grams} \times 40$$

24. The yardage per pound of rayon of any given denier may be calculated by the following formula:

$$\text{Yards per pound of rayon} = \frac{\text{4,464,528 (yards per pound of one denier yarn)}}{\text{Given denier}}$$

STRENGTH

(*A*) *Preferred Method*

Test Skeins

25. One skein from each of the ten spools, cops, tubes, cones or skeins drawn for a sample shall be prepared as described in Sections 18 and 19. The number of turns in these strength skeins shall be as specified in Table I. For deniers which require 200 ends, ten of the test skeins (Section 20), may be used if desired.

TABLE I.

SPECIFIED DENIER OF RAYON	NUMBER OF TURNS IN STRENGTH SKEIN
Finer than 51 denier	400
51 to 76 denier	200
76 to 121 denier	150
121 to 201 denier	100
201 denier and coarser	50

Conditioning

26. The test skeins shall be conditioned for at least 3 hr. in an atmosphere, kept in rapid motion by an electric fan, having a relative humidity of 65 per cent at 70 F. (21 C.).

Apparatus

27. (*a*) *Machine.*—The test skeins shall be broken on a tensile testing machine of the pendulum type of 25-kg. (55-lb.) or 50-kg. (110-lb.) capacities. The pulling jaw shall travel at a speed of 6 in. per min.

(*b*) *Recording Device.*—The machine shall be equipped with an automatic charting device to record stretch at any load.

(*c*) *Jaws.*—Clamps for holding the test skeins shall consist of flat metallic jaws. These shall be covered with one layer of rubber tire tape which shall press directly against the specimen. One gripping surface shall be hinged or swiveled and the other shall be rigidly connected to the frame of the jaw. The pressure between the jaws shall be secured by any suitable mechanical device so constructed as to grip the yarns firmly before the testing load is applied and prevent slipping during the progress of the test.

(*d*) Any tendency to friction, backlash, or play in the recording device, lower jaw, or screw, shall be overcome as far as practicable by counter balancing.

Procedure

28. Immediately after conditioning (Section 26), the test skeins shall be separately broken on the testing machine. The initial distance between jaws shall be 10 cm. (4 in.). The skein to be tested shall first be clamped in the upper jaws, spread out evenly so that the ends are parallel forming a ribbon approximately $\frac{3}{8}$ to $\frac{3}{4}$ in. in width. The rayon shall then be drawn down through the lower jaws and spread out to make a band of equal width, pulled just taut and clamped. The lower capacity machine shall be used until the swing of the pendulum exceeds an angle of 45 deg. from the vertical. When the yarns break above this mark, the higher capacity of testing machine shall be used.

Number of Tension Tests

29. One test shall be made on each of the 10 skeins prepared as described in Section 25 and the average of these 10 tests shall be the tensile strength.

B. Alternate Method

Apparatus

30. A single strand tester of proper capacity with the jaws set 10 in. between grips and having a speed of pulling jaw of 12 in. ± ½ in. per min. shall be used.

Procedure, Alternate Method

31. Five single strands from each of 10 spools, cops, tubes, cones, or skeins shall be broken after conditioning the skeins for 3 hr. and any other form of package for 12 hr. in an atmosphere, kept in rapid motion by an electric fan, having a relative humidity of 65 per cent at 70 F. (21 C.).

Number of Tension Tests

32. The average of 50 tests shall be the tensile strength.

TWIST

Twist Specimen

33. The specimen of yarn for twist determination shall be drawn from the side of the package instead of over the end in order to avoid changing the twist.

Twist Test Procedure

34. The twist shall be determined in any standard twist tester with jaws set 10 in. apart. The yarn shall be clamped in the jaws under a definite tension by attaching a weight. The tension weight to be used shall be as follows:

YARN	TENSION WEIGHT
75 denier and finer	10 g.
150 denier to 75 denier	20 g.
Coarser than 150 denier	30 g.

NOTE.—Where yarn is unraveled from cloth for test, it is recommended that the tension weight specified be increased by 10 g. in each classification.

Twist Calculation

35. Two samples of yarn from each of five spools, cops, tubes, cones, or skeins shall be tested and the average of these 10 tests calculated to turns per inch shall be the twist.

MOISTURE REGAIN

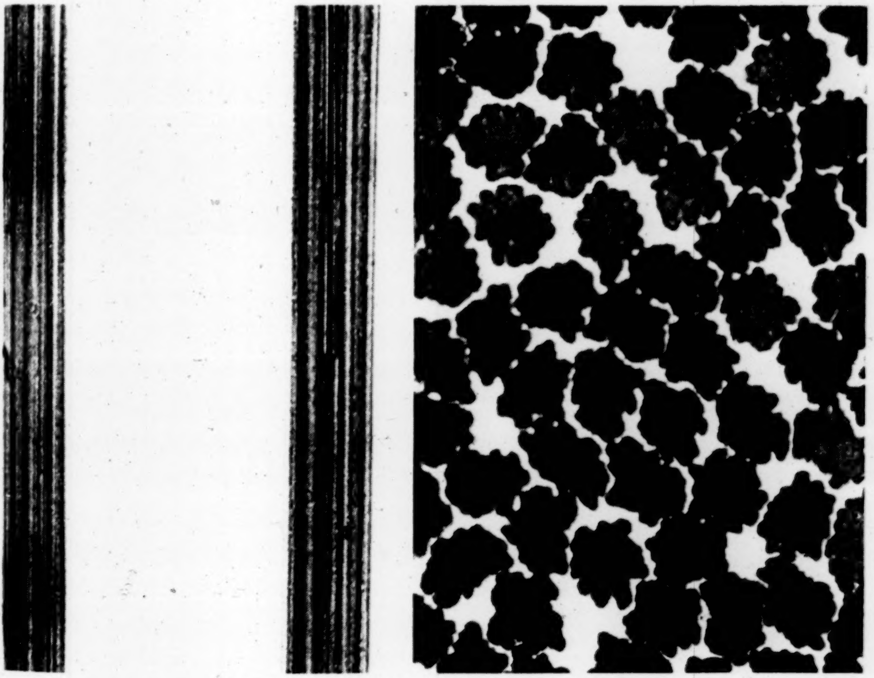
Moisture Regain

36. The standard moisture regain of nitrocellulose, viscose and cuprammonium rayons shall be 11 per cent of the moisture-free weight.

37. The standard moisture regain of cellulose-acetate rayons shall be 6.5 per cent of the moisture-free weight.

APPENDIX

PHOTOMICROGRAPHS OF RAYON FIBERS

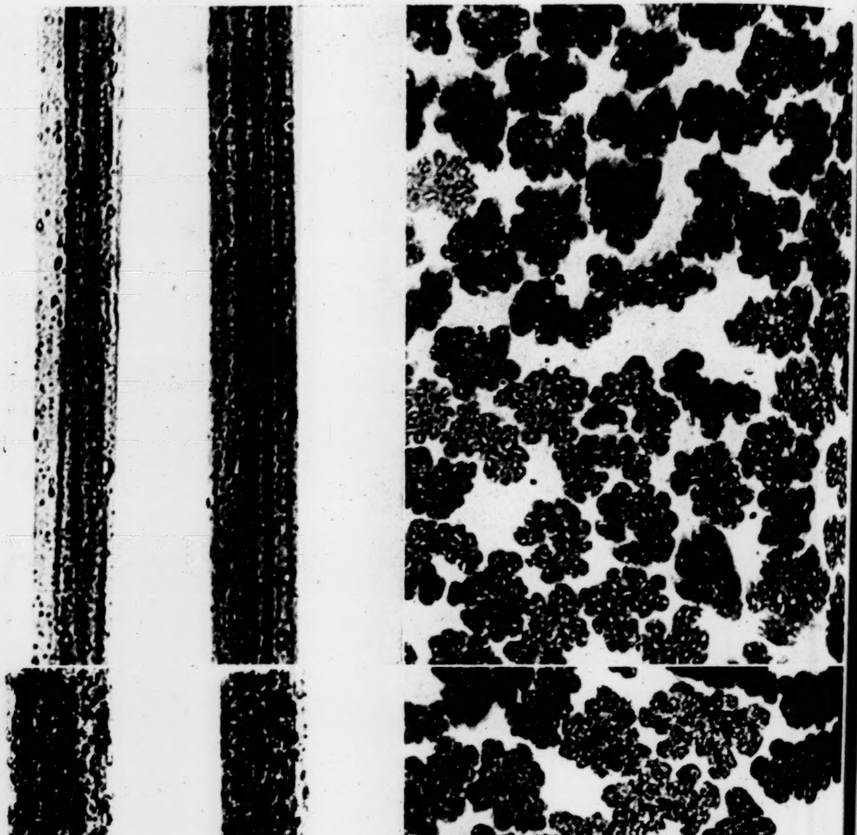


Courtesy of *Bureau of Animal Industry, United States Department of Agriculture*

(*a*) Longitudinal View. (*b*) Cross-Section.

Fig. 1.—Viscose Rayon Fibers, Bright (× 500).

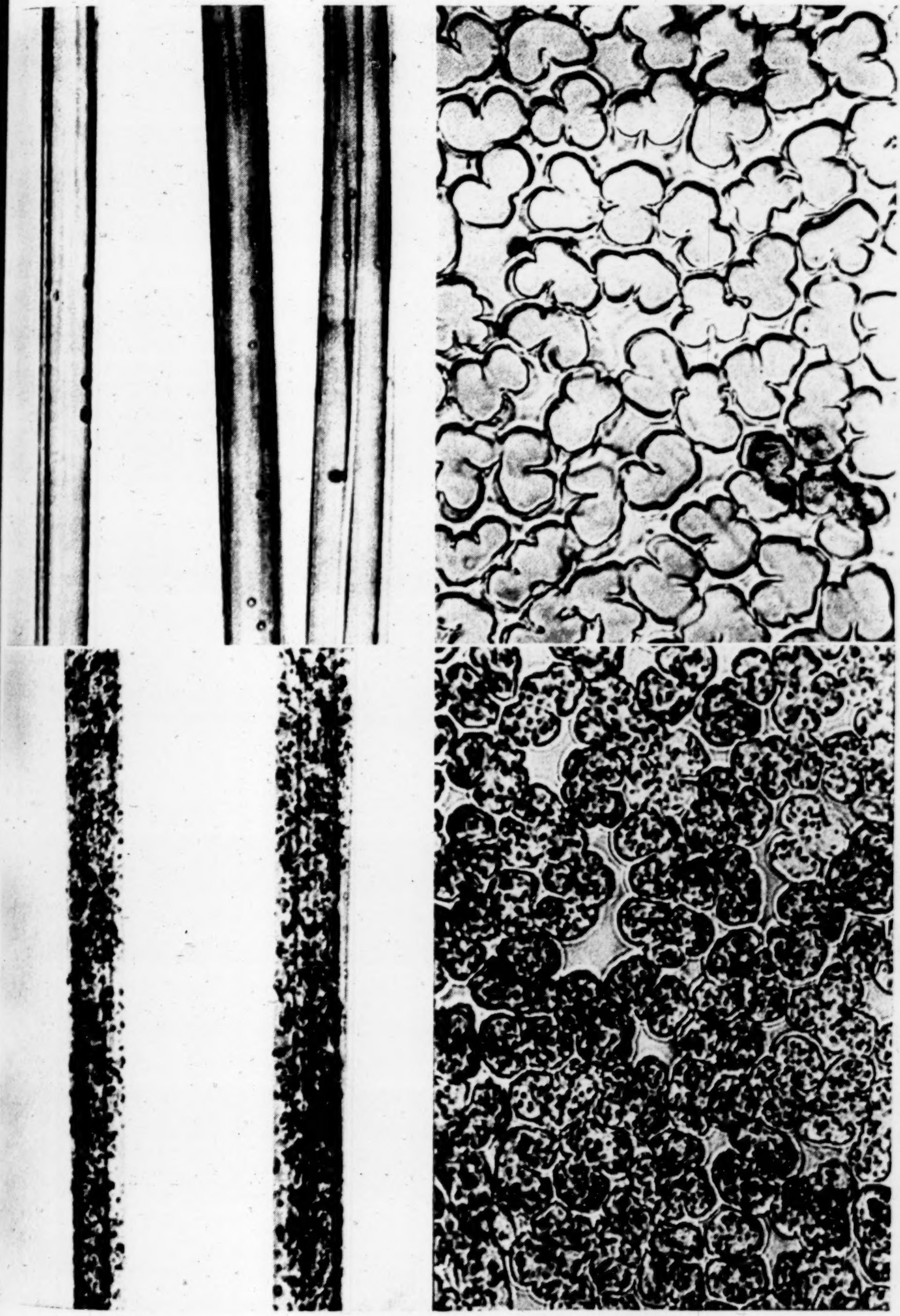
(*a*) Longitudinal View, Semidull. (*b*) Cross-Section, Semidull.



Courtesy of *Bureau of Animal Industry, United States Department of Agricultur*

(*c*) Longitudinal View, Dull. (*d*) Cross-Section, Dull.

FIG. 2.—Viscose Rayon Fibers (× 500).



(*a*) Longitudinal View, Bright.

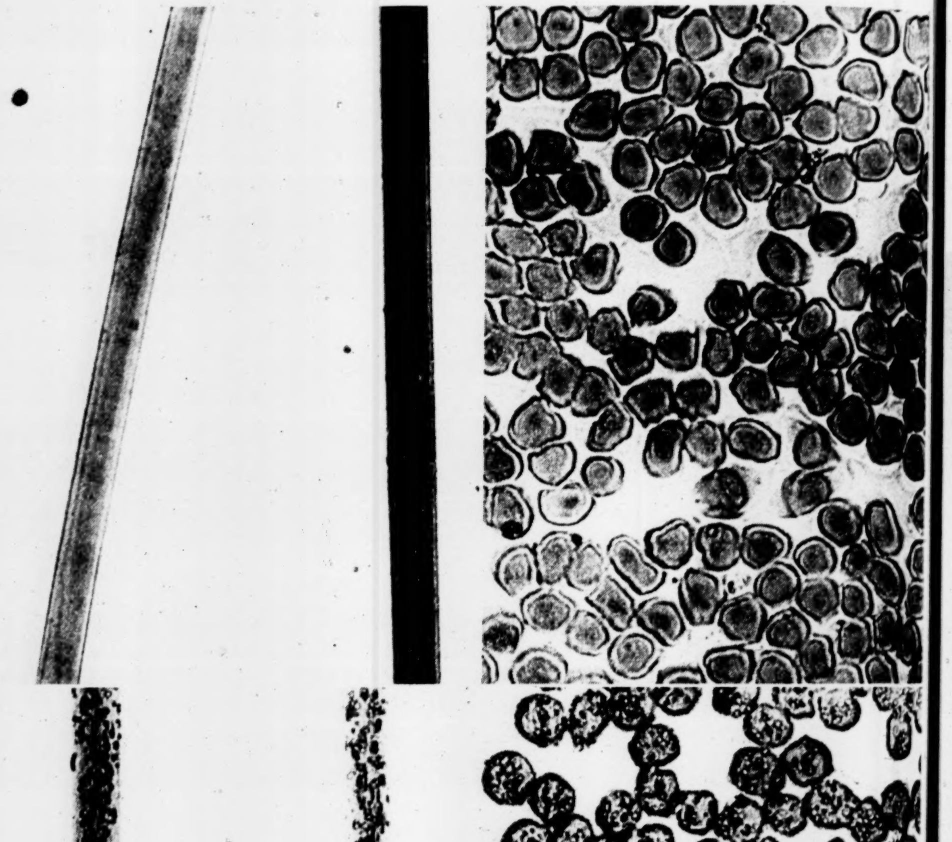
(*b*) Cross-Section, Bright.

Courtesy of *Bureau of Animal Industry, United States Department of Agriculture*

(*c*) Longitudinal View, Dull.

(*d*) Cross-Section, Dull.

FIG. 3.—Acetate Rayon Fibers (× 500).



(*a*) Longitudinal View, Regular Luster.

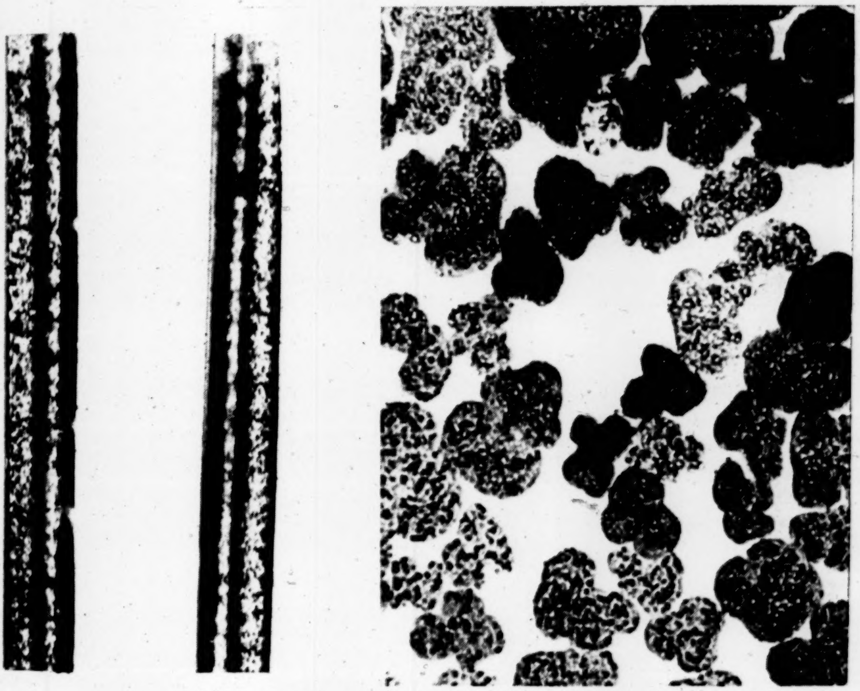
(*b*) Cross-Section, Regular Luster.

Courtesy of *Bureau of Animal Industry, United States Department of Agriculture*

(*c*) Longitudinal View, Semidull.

(*d*) Cross-Section, Semidull.

FIG. 4.—Cuprammonium Rayon Fibers (× 500).



Courtesy of *Bureau of Animal Industry, United States Department of Agriculture*

(*a*) Longitudinal View. (*b*) Cross-Section.

FIG. 5.—Nitrocellulose Rayon Fibers, Dull (× 500).

TENTATIVE METHOD OF TEST
FOR
SHRINKAGE IN LAUNDERING OF SILK AND RAYON WOVEN BROAD GOODS[1]

A.S.T.M. Designation: D 416 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. This method covers the test procedure for determining the shrinkage of silk and rayon woven broad goods in commercial laundering and for general technical purposes.

Test Sample

2. The sample of cloth for test shall be from 12 to 13 in. square, and shall be taken at least 2 in. from the selvage and 3 ft. from the ends of the roll or piece. It shall be laid out without tension on a flat surface, care being taken that the cloth is smooth and free from wrinkles and creases. The corners and the mid-points of the sides of a 10-in. square, whose center is the center of the sample and whose sides are aligned with the warp and filling threads, shall be marked on the sample. This gives three 10-in. distances in both warp and filling directions, all laying at least 1 in. from the edge of the sample. Satisfactory marks may be made with an inking pen using indelible ink or by sewing fine threads into the cloth at the point from which measurements are taken. In the case of dark colored fabrics the marking may be done with light colored thread or by means of a color resistant to washing. Tests shall be made on at least three samples from each fabric. When only three tests are made, no two samples shall include the same set of yarns.

Washing Machine

3. The test shall be carried out in a Launder-Ometer or similar machine. The essential features are that a 1-pt. preserve jar be held with its base toward a horizontal shaft 2 in. from the center of rotation, and the shaft rotated at a speed of from 40 to 45 r.p.m., provision being made to maintain the jar at a temperature of 100 F. ±2 F. (38 C. ±1.1 C.).

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Soap Solution

4. A soap solution containing 0.5 per cent neutral soap shall be used. The solution and the rinse water shall be maintained at 100 F. ±2 F. (38 C. ±1.1 C.).

Method of Washing

5. The sample shall be placed in the 1-pt. preserve jar with 300 ml. of soap solution. The jar shall be placed in the washing machine and the machine operated for 15 min. The sample shall be removed from the jar, rinsed by dipping in three changes of water, returned to the jar with 300 ml. of water, and the jar placed in the machine. The machine shall then be operated for 5 min. The sample shall be removed and, without squeezing, laid out on a smooth horizontal surface. Wrinkles shall be removed by gently pressing the sample with the palm of the hand. When the excess of water has evaporated but the sample is still appreciably damp, the sample is ready to be pressed. If desired, the sample may be allowed to come to complete dryness and then, when ready for pressing, may be covered with a thin muslin saturated with water and pressed with the cloth in place.

Method of Pressing

6. The sample shall be smoothed to remove wrinkles before pressing, care being taken to avoid any strain on the cloth. The sample shall be pressed with a flat-bed press at a temperature between 275 and 300 F. (135 and 149 C.), the press being applied only long enough to remove the moisture. An alternate method of pressing shall consist of the use of a metal plate (aluminum preferred) not less than $\frac{1}{16}$ in. in thickness and covering the entire sample. On this plate a hand iron may be used to furnish the heat necessary to remove the moisture. The plate shall not be moved during the operation.

Conditioning

7. The pressed sample shall be allowed to lie on a horizontal surface for at least 2 hr. at room temperature and humidity before it is measured. No sample shall be allowed to remain more than 16 hr. before measuring.

Results

8. The conditioned sample (Section 7) shall be laid out without tension on a flat surface, care being taken that the cloth is smooth and free from wrinkles and/or creases. The distances which were marked off shall be measured again. The shrinkage in the warp and in the filling shall be calculated separately as the average obtained from the three marked distances. The shrinkage in laundering is the decrease in the distance measured and shall be expressed either as a percentage of the dimension before laundering or in inches per yard.

TENTATIVE METHOD OF TEST
FOR
STRENGTH OF RAYON WOVEN FABRIC WHEN WET[1]

A.S.T.M. Designation: D 415 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.

Scope

1. This method covers the test procedure for determining the change in strength which a rayon woven fabric undergoes when wetted.

Test Samples

2. Fourteen test samples, each 4 by 6 in. shall be cut from the fabric, seven with the length running in the direction of the warp and seven with the length running in the direction of the filling. The location in the fabric of those samples used for strength determinations shall be such that the same sets of threads are included in the samples for both the nomral and the wet strength tests. No sample shall be cut within 1 in. of the selvage.

Strength

3. (*a*) *Normal.*—Six samples, three for warp strength and three for filling strength, shall be exposed for at least 4 hr. in an atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.). They then shall be tested for breaking strength by the grab method as described in Section 12 (*b*) of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[2] The average of the three individual tests on the warp shall be taken as the normal strength of the warp, and the average of the three individual tests on the filling shall be taken as the normal strength of the filling.

(*b*) *Wet.*—Eight samples shall be immersed in tap water at room temperature for 2 hr. Six of them, three samples each from the warp and filling shall be removed one at a time and tested immediately for breaking strength, using the grab method as specified in Paragraph (*a*). The test of any sample shall be completed within 1 min. after its removal from the water.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] 1934 Supplement to Book of A.S.T.M. Standards, p. 204.

Count

4. (*a*) *Normal.*—Using the conditioned samples (Section 3 (*a*)), determine the average number of ends and of picks per inch of the fabric by counting a space not less than 1 in. in three different places, so taken as not to include the same set of threads. The average number of ends and of picks shall be taken as the normal warp and filling count, respectively.

(*b*) *Wet.*—Using the remaining two samples which have been immersed in water (Section 3 (*b*)), determine the average number of ends and of picks in the same manner as described in Paragraph (*a*). The count must be made immediately upon removal of the sample from the water and in such a way as to prevent drying. The average number of ends and of picks shall be taken as the wet warp and filling count, respectively.

Report

5. (*a*) *Normal Strengths.*—Report as normal strengths the averages of the warp and of the filling strengths, respectively, as determined in Section 3 (*a*).

(*b*) *Uncorrected Wet Strengths.*—Report as uncorrected wet strengths the averages of the warp and of the filling strengths, respectively, as determined in Section 3 (*b*).

(*c*) *Corrected Wet Strengths.*—Report as corrected wet strengths the results obtained by multiplying the uncorrected strength (warp or filling) by the normal count (warp or filling) (Section 4 (*a*)), and dividing by the wet count (warp or filling) (Section 4 (*b*)).

(*d*) *Change in Strength.*—Report as change in strength the difference between the normal strength (warp or filling) and the corrected wet strength (warp or filling).

NOTE.—If only the change in strength due to wetting, without regard of effect of shrinkage, is desired, the difference between the results reported in Paragraphs (*a*) and (*b*) of Section 5 should be used.

TENTATIVE METHODS OF TESTING AND TOLERANCES
FOR
TUBULAR SLEEVING AND BRAIDS[1]

A.S.T.M. Designation: D 354 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1932; Revised, 1935.

Scope

1. These methods of testing and tolerances apply to fabric tubular sleeving, including braid.

TOLERANCES

Tolerances

2. Tolerances shall be the limits within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract.

Wall Thickness

3. The wall thickness of sleevings and braids shall not vary from that specified by more than the following amounts:

Wall Thickness, in.	Permissible Variations	
	Sleeving with One End per Carrier	Sleeving with More Than One End per Carrier
Up to and including 0.010	±0.001 in.	±0.002 in.
Over 0.010 and including 0.020	±0.0015 in.	±0.003 in.
Over 0.020	±0.002 in.	±0.004 in.

Inside Diameter

4. The inside diameter of sleevings and braids shall not vary from that specified as nominal by more than the following amounts:

Nominal Inside Diameter, in.	Permissible Variations
Up to and including $\frac{3}{16}$	$+\frac{1}{64}$ in.
Over $\frac{3}{16}$ and including $\frac{3}{8}$	$+\frac{1}{32}$ in.
Over $\frac{3}{8}$	$+\frac{1}{16}$ in.

Carrier

5. The number of carriers shall be not less than specified.

Ends on Bobbin

6. The ends on the bobbin shall not exceed the number specified.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

Yarn Number

7. The yarn number in singles shall not vary more than 5 per cent above or below the specified number.

Weight

8. The weight of the sleeving or braid shall be calculated in yards per pound and in no case shall the yardage be less than that specified.

Imperfections

9. All knots and imperfections are objectionable and shall be held to a minimum. Sleeving or braid containing more than 2 knots and 4 imperfections in any 5-lb. bundle will not be considered satisfactory and continued offense in this respect shall be a basis for rejection.

METHODS OF TESTING

Wall Thickness

10. The thickness of the wall shall be determined by inserting a mandrel of the nominal inside diameter of the sleeving or braid in the sample and measuring the outside diameter. Such measurements shall be made in accordance with Method B of the Tentative Methods of Test for Thickness of Solid Electrical Insulation (A.S.T.M. Designation: D 374 – 34 T) of the American Society for Testing Materials.[1] By subtracting the mandrel diameter from the outside diameter and dividing the difference by two, the wall thickness is determined.

Number of Measurements

11. At least ten measurements of wall thickness shall be made on the samples used for weight determination and the average and range of thickness recorded.

Inside Diameter

12. The inside diameter of sleeving or braid shall be determined by the use of a mandrel of the specified diameter and having a hemispherical end. The mandrel shall be at least 6 in. in length. When a sample of the sleeving approximately 6 in. long is taken, a length of at least 3 in. when held firmly in the palm of the hand shall slide freely on the mandrel without disturbing the construction due to forcing the sample onto the mandrel. In sleeving of nominal diameter up to and including $\frac{3}{8}$ in., a mandrel $\frac{1}{64}$ in. over the nominal diameter shall just enter the sleeving; in sleeving over $\frac{3}{8}$ in. in nominal diameter a mandrel $\frac{1}{32}$ in. over the nominal diameter shall just enter the sleeving.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1069 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1087.

Samples for Test

13. Inside diameter measurements shall be made on the samples selected for weight determinations.

Carriers

14. The number of carriers shall be determined by cutting the sample at right angles to the axis of the sleeving and counting the total number of ends and dividing by the average number of ends per bobbin.

Samples for Test

15. Carrier determinations shall be made on the samples used for making inside diameter measurements.

Ends on Bobbin

16. The ends on the bobbin are the "number of ends up" or the number of ends in each web or tape. Ends on bobbin determinations shall be made at the time the carrier determinations are made.

Yarn Number

17. In determining the yarn number, an assorting yarn balance or similar device shall be used. It will be necessary to carefully ravel individual ends from the braid and from these the number will be calculated automatically by the testing device.

Samples for Test

18. Yarn number shall be determined on the samples used for weight determinations.

Weight

19. A sample approximately 1¼ yd. in length shall be measured off while the sleeving or braid is laid flat on a smooth surface. The sample shall then be suspended vertically from a clamp gripping the full width of the sample and a 2-oz. weight shall be suspended from the lower end. The sample shall be allowed to remain under these conditions approximately 10 minutes and then a 1-yd. length shall be measured off and cut from the suspended sample. This length shall then be weighed and the yards per pound calculated.

Number of Determinations

20. Not less than three weight determinations shall be made per shipment. Samples shall be removed from different bundles and the average of the three determinations shall indicate the average of the shipment involved.

Imperfections

21. The number of knots or imperfections shall be determined on any bundle by a visual examination.

Number of Tests

22. From each shipment of sleeving or braid at least three bundles shall be selected and tests shall be made on lengths cut from each bundle. Failure of the first samples selected to conform to requirements of these specifications will necessitate the selection of a second set of bundles for a second test.

Referee Conditions

23. In case of dispute, tests shall be made under standard conditions as defined in Section 3 of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials.[1]

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[1] 1934 Supplement to Book of A.S.T.M. Standards, p. 204.

TENTATIVE METHODS OF TEST
FOR
FINENESS OF WOOL[1]

A.S.T.M. Designation: D 419 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. These methods of test are intended for estimating the fineness of wool in loose form, top or roving. They are also applicable to similar hairs such as mohair, alpaca, camel hair, cashmere, vicuna and rabbit hair.[3]

WIDTH METHOD

Fineness

2. The fineness of the wool determined in accordance with the width method shall be expressed in terms of the arithmetical mean width in microns, of at least 200 fibers, and by the standard deviation or other methods of representing dispersion.

Sampling

3. (*a*) For loose wool, the thoroughly cleaned samples representing a good average of the lot to be tested shall be carded for thorough mixing. From the sliver produced, two samples 2 in. in length, each containing about 120 single fibers, shall be cut out with a pair of scissors.

(*b*) For top and roving, samples shall be cut from at least two different packages.

Width Method

4. The width method is based on the projection of the image of the fiber at a high magnification through a microscope on a wedge ruler. The width of the image of the fiber is recorded on the wedge ruler by which the fibers are automatically sorted according to their width.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935

[3] Attention is called to the photomicrographs of wool, camel's hair and mohair fibers, shown in Figs. 5 to 7 of Appendix I of the volume of "A.S.T.M. Standards on Textile Materials," pp. 190 and 191; available as a separate publication, October, 1935.

Further information covering the procedures described in these methods appears in a paper by Werner Von Bergen on "Testing the Physical and Chemical Properties of Wool by Means of the Microscope," see *Proceedings*, Vol. 35, Part II (1935).

Apparatus

5. (*a*) *Microscope.*—The microscope shall have a movable stage and fixed body tube, objective and eyepiece to give a magnification of 500 diameters, and shall be built for projection.

(*b*) *Wedge Ruler.*—The wedge ruler shall consist of a sheet of white cardboard on which is printed two wedges as shown in Fig. 1.

Measurement of Width

6. The samples shall be carefully opened so that each fiber is freed, mounted across the slides in c. p. glycerine and then covered with a cover-glass. The slide shall be placed on the stage and the image projected on a wedge ruler. The wedge ruler shall be turned until the image of the fiber to be measured is projected directly between the two lines of the wedge. The place where the wedge has exactly the same width as the image of the fiber shall be marked. One hundred fibers shall be recorded on each of two wedges.

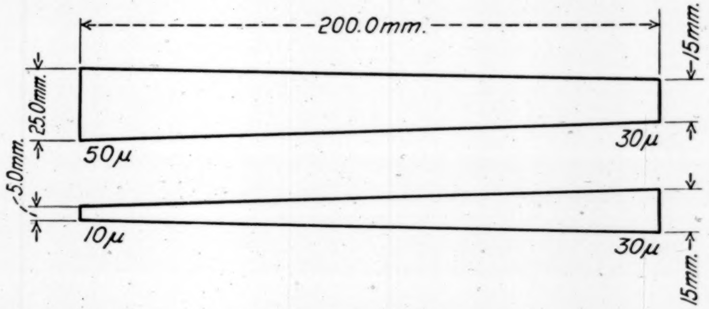


FIG. 1.—Wedge Ruler.

Calculation

7. From the wedge markings, the fineness of the fibers shall be expressed in accordance with Section 2.

CROSS-SECTION METHOD

Fineness

8. The fineness of wool determined in accordance with the cross-section method shall be expressed in terms of the arithmetical mean diameter in microns, of at least 200 fibers measured in two directions at right angles to each other and by the standard deviation or other means of representing dispersion.

Sampling

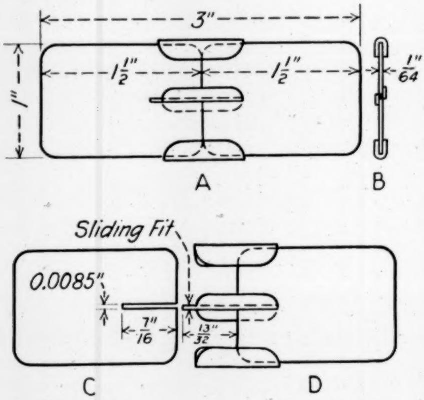
9. (*a*) The sample shall be representative of the lot to be tested, and if taken from loose wool shall be well mixed by carding. In all cases the

portion of the sample used for making cross-sections shall be thoroughly cleaned.

(*b*) For top and roving, samples shall be taken from at least two different packages.

Cross-Section Method

10. In the cross-section method, the image of cross-sections of fibers is projected through a microscope upon sensitized paper, at a magnification of 500 diameters. The sensitized paper is then developed, fixed and dried. The images of the fibers on the paper are measured in two directions at right angles to each other by means of a celluloid wedge measure, graduated to read directly in microns.



A = Assembly
C = Fiber Holder
B = Side View
D = Slide Holder

FIG. 2.—Cross-Section Device.

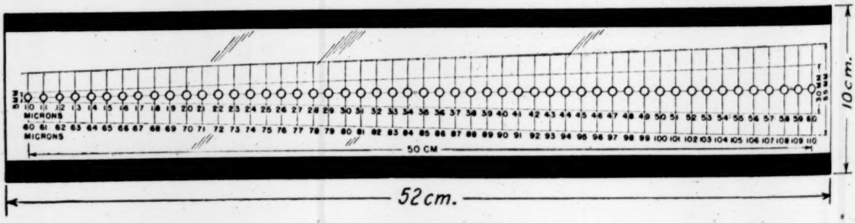


FIG. 3.—Wedge Measure.

Apparatus

11. (*a*) *Microscopes.*—Laboratory and dissecting microscopes and a projection microscope equipped with a right-hand prism will be required.

(*b*) *Cross-Section Device.*—The cross-section device illustrated in Fig. 2 shall be used in making the cross-sections of the fibers. It consists of two parts the fiber holder, *C*, with the fiber slot, and the slide holder, *D*, in which is rigidly held a flat surfaced metal plunger, with right angle flanges to fit in the slot of the fiber holder (sliding fit). When assembled, the shape of the cross-section device is as that of a microscopic slide, 1 in. in witdh and 3 in. in length. The guides on each side of the slide holder keep the fiber holder steady and help hold the fiber and slide holder together, as shown in the side view, *B*.

(*c*) *Wedge Measure.*—The wedge measure illustrated in Fig. 3 shall be made from celluloid 0.0020 in. in thickness.

Making and Projecting Cross-Sections

12. (*a*) A tuft of about 150 fibers shall be withdrawn from the cleaned sample, care being taken not to disturb the distribution of the fibers as they occur in the sample. This tuft of fibers shall be inserted in the fiber holder and the slide of the slide holder pushed into the fiber slot until the fibers are held securely in place. The slide of the slide holder should have just sufficient tension upon the fibers to hold them without distorting their shape. The fibers shall be cut off close on both sides of the fiber holder with scissors. A drop of celluloid solution shall be applied on one side and allowed to dry. The fibers shall then be cut off flush on both sides of the fiber holder by means of a sharp razor blade, the edge of which shall appear smooth and free from nicks when examined under the microscope at a magnification of 100 diameters. When cutting the fibers, the bevel of the razor blade shall be kept parallel to the surface of the fiber holder. This may best be accomplished by using a binocular microscope, magnifying about 12 diameters. After the cross-section is made, it shall be examined under a microscope at a magnification of about 300 diameters. When the fibers are all smoothly cut and each fiber is clearly defined, the cross-section is ready for projection.

(*b*) With the projection microscope set for a magnification of 500 diameters, the cross-section device shall be placed on the stage of the microscope and the image of the cross-section shall be focused through an orange color filter upon a sheet of white paper. The illumination should be uniform for different cross-sections. To secure this condition a filter of the proper depth of color should be used according to the intensity of the light passing through the cross-section.

Measuring Fibers for Fineness

13. By means of the celluloid wedge measure the cross-sections of the fibers shall be measured in microns for their greatest and least diameters, at right angles to each other. As each fiber is measured, it shall be numbered through the hole in the wedge.

Calculations

14. The fineness of each fiber shall be obtained by averaging its greatest and least diameters. From the difference between the average of the greatest and least diameters of the fibers in the cross-sections, a measure may be obtained of the circularity of the fibers in the sample. Other statistical values may be obtained as set forth in Section 8.

TENTATIVE METHOD OF ESTIMATING HARD SCOURED WOOL IN WOOL IN THE GREASE[1]

A.S.T.M. Designation: D 232 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1925; REVISED, 1934, 1935.

Scope

1. This method of test is intended for estimating hard scoured wool in wool in the grease and is applicable to any shipment of wool in the grease, whether in the form of fleeces, necks, pieces, bellies, pulled wool, or colonial scoured. It is also applicable to shipments of similar hairs such as mohair, alpaca, camel hair, cashmere, and vicuna.

Standard Regain

2. The standard regain of hard scoured wool shall be 13.6 per cent which is equivalent to 12 per cent moisture content.

Sampling

3. The entire shipment shall be sorted into the different kinds or grades of wool which it contains. The total net weight of each kind or grade shall be recorded separately. A sample of not less than 5 per cent of the lot, and in no case less than 500 lb., shall be selected as representative of each kind or grade of wool.

Scouring

4. (*a*) Each sample shall be scoured separately in a commercial type of scouring equipment having not less than four bowls and using an alkaline detergent, or using a solvent extraction process. The sample shall be air-dried after scouring.

(*b*) The sample shall be considered as having been properly scoured when it conforms to the following requirements:

Free Fat, max., per cent	fine wools (64's and finer)	1
	medium and heavier wools ($\frac{1}{4}$ to $\frac{3}{8}$ blood and coarser)	$1\frac{1}{2}$
Soap Fat, max., per cent		1
Ash, max., per cent	fine or medium wools	1
	coarse wools	3
pH		below 10

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M Committee D-13 on Textile Materials.

Free Fat

5. (*a*) Three 10-g. samples (approximate) shall be extracted separately in a Soxhlet apparatus for 20 extractions with alcohol-free ethyl ether (Note). In the bottom of the Soxhlet apparatus there shall be lightly placed a thin layer of cotton, previously extracted with ethyl ether, as a filter covering the opening of the siphon tube. The ether then shall be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is free fat.

NOTE.—C.p. carbon tetrachloride shall be substituted for ethyl ether for Code Work.

Soap Fat

(*b*) The samples from which the free fat has been removed (Paragraph (*a*)) shall be extracted in a Soxhlet apparatus for 12 extractions with neutral 95 per cent alcohol. The alcohol shall then be evaporated from the extract. After adding 25 to 30 ml. of 0.1 *N* HCl this shall be boiled and cooled. The solution shall then be shaken with an equal volume of neutral ether and decanted. This shall be repeated twice. The three ether extracts shall be combined and washed once by shaking with an equal volume of distilled water and then decanted. The ether shall then be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is soap fat.

Weight, Oven-Dry Extracted Wool

(*c*) The extracted wool (Paragraph (*b*)) shall be dried to constant weight at 220 to 230 F. (105 to 110 C.).

Ash

6. A 2 to 3-g. sample of scoured wool shall be accurately weighed. The sample shall then be ignited to constant weight in a porcelain crucible and the final weight recorded. This residue is the ash.

NOTE.—Wool is apt to swell and froth when heated. To avoid loss, the sample may be burned in small portions, or it may be moistened with a saturated solution of ammonium nitrate in 67 per cent alcohol.

pH

7. Ten grams of wool shall be immersed in 200 ml. of distilled water (pH 6 to 7) in a 500-ml. Erlenmeyer flask. The flask must be closed to prevent the influence of carbon dioxide from the air. After soaking for 20 min. at room temperature, the pH shall be determined.

Moisture

8. A sample of approximately 200 g. of scoured wool shall be accurately weighed and then dried to constant weight at 220 to 230 F. (105 to 110 C.). The final weight shall be recorded.

Calculation of Results

9. (*a*) From the results obtained in Section 8, determine the percentage of regain in the scoured sample. Calculate the weight of the scoured sample under conditions of standard regain. Calculate the percentage of scoured wool with standard regain on the basis of the weight of the sample before scouring. Multiply this percentage by the net weight of the wool represented by the sample to find the amount of scoured wool contained in the greasy wool tested.

(*b*) The percentage of free fat, soap fat and of ash may be calculated on a dry or a standard regain basis by the following formulas:

$$\text{Free Fat (dry basis), per cent} = \frac{F \times 100}{W + F + S}$$

$$\text{Soap Fat (dry basis), per cent} = \frac{S \times 100}{W + F + S}$$

$$\text{Ash (dry basis), per cent} = \frac{A \times 100}{W + F + S}$$

$$\text{Free Fat (standard regain basis), per cent} = \frac{F \times 100}{\frac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

$$\text{Soap Fat (standard regain basis), per cent} = \frac{S \times 100}{\frac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

$$\text{Ash (standard regain basis), per cent} = \frac{A \times 100}{\frac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

where A = the weight of ash
F = the weight of free fat
S = the weight of soap fat
W = the weight of oven-dry extracted wool

TENTATIVE METHODS OF TESTING AND TOLERANCES
FOR
WOOLEN YARNS[1]

A.S.T.M. Designation: D 403 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.[2]

Scope

1. These methods of testing and tolerances apply to single or plied woolen yarns of any of the following three types:

Scoured Spun in Oil Yarn, made from thoroughly scoured wool to which oil has been added;

Semiscoured Spun in Oil Yarn, made from wool which has been washed at the source but not scoured, and to which oil has been added;

Dry Spun Yarn, made from thoroughly scoured wool without the addition of oil.

Materials and Workmanship

2. The yarn shall be reasonably clean and free from slubs and shall be reasonably uniform in diameter in view of the purpose for which it is to be used.

Packing and Marking

3. Each case, beam, or other package of yarn shall be plainly marked with the name of the vendor, the net and gross weights, and some means of identifying the contract under which it was delivered.

Rejection

4. Yarn may be rejected if it fails to meet any of the requirements specified. In case of rejection, the vendor must be notified within 10 days of the shipment.

Definitions

5. (*a*) *Yarn Number.*—The number of a woolen yarn shall be the number of thousands of yards per pound (Typp System).[3]

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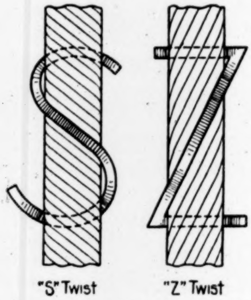
[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

[3] See the Yarn Number Conversion Table which appears as Appendix II of the volume of "A.S.T.M. Standards on Textile Materials," p. 199; available as a separate publication, October, 1935; also appended to the 1935 Report of Committee D-13 on Textile Materials, see p. 452.

(*b*) *Direction of Twist.*—The direction of twist shall be as defined in the Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 – 35 T) of the American Society for Testing Materials, as follows:

Twist, Direction of.—A yarn or cord has "S" twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and "Z" twist if the spirals conform in slope to the central portion of the letter "Z."



(*c*) *Standard Regain.*—The standard regain for woolen yarn shall be 13 per cent, which is equivalent to 11.5 per cent moisture content.

(*d*) *Standard Condition.*—Standard condition of woolen yarn shall be that reached by the yarn in equilibrium with an atmosphere having a relative humidity of 65 per cent ± 2 per cent at 70 to 80 F. (21 to 27 C.).

(*e*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when two successive weighings not less than 15 min. apart show not more than 1.0 per cent change in weight.

TOLERANCES

Tolerances

6. Tolerances shall be the limits within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract.

7. Woolen yarns shall conform to the following tolerances. Where averages are used the number of tests shall be reported and the standard deviation or some other method of dispersion indicated.

(*a*) *Weight.*—The net weight of the shipment of yarn shall be calculated to the basis of standard regain.

(*b*) *Yarn Number.*—The average yarn number shall be as specified within the following permissible variations:

		Permissible Variations
Single Yarns	Coarser than No. 3	± 10 per cent
	Nos. 3 to 6	± 7.5 per cent
	No. 6 and finer	± 5 per cent
Plied Yarns		± 5 per cent

(*c*) *Twist.*—The average twist of yarn from all of the packages tested shall not vary more than ±7½ per cent from the specified twist. The average twist of yarn from any one package shall not vary more than ±7½ per cent from the average for any other package in the shipment.

(*d*) *Direction of Twist.*—The direction of twist shall be as specified.

(*e*) *Breaking Strength.*—The breaking strength of yarn shall be not less than that specified.

(*f*) *Fat Content.*—Scoured spun in oil yarn shall contain not more than 7 per cent of fat; semiscoured spun in oil yarn, not more than 15 per cent of fat; and dry spun yarn, not more than 2 per cent of fat.

METHODS OF TESTING

Sampling

8. (*a*) Samples shall be so selected as to be fairly representative of the shipment.

(*b*) For yarn on cones, spools, or bobbins, four cones, spools, or bobbins shall be selected from each case of yarn.

(*c*) For yarn on beams, each beam of yarn shall be tested separately.

Preparation of Skeins

9. Standard skeins of 120 yd. shall be prepared by winding the yarn on a reel having a perimeter of 1½ yd. Care must be used to maintain uniform tension. The yarn shall make one full turn around single guides or pass straight through double guides. It is preferable to equip yarn reels with motors.

Yarn Number

10. Standard skeins shall be weighed to an accuracy of 0.25 per cent and the yarn number calculated. The yarn number shall be the arithmetical mean of the results.

Breaking Strength

11. (*a*) *Skein Method.*—A conditioned skein shall be broken on an approved type of testing machine. The drums of the machine shall be cylindrical spools not less than 1 in. in diameter and width, at least one of which shall be free to turn on its axis. The speed of the pulling drum when running free shall be 12 in. ± ½ in. per minute. The average skein breaking strength shall be the arithmetical mean of the results.

(*b*) *Single Strand Method.*—A conditioned single strand shall be broken on an approved type of testing machine with the jaws set 10 in. apart. The speed of the pulling jaw when running free shall be 12 in. ± ½ in. per minute. The average single strand breaking strength shall be the arithmetical mean of the results.

Twist

12. (*a*) *Single Yarns.*—The first 2 yd. of any package of yarn shall be discarded. The yarn, drawn just taut enough to prevent sagging, shall be clamped in a twist counter with jaws set 4 in. apart. One jaw shall be rotated until the twist is removed as indicated by passing a sharp pointed needle from jaw to jaw. Not more than $\frac{1}{2}$ in. of yarn shall be left out between individual tests. The twist of a shipment shall be the average of 80 tests taken at 20 continuous lengths of each of four strands. Care must be taken that the yarn is drawn from the side of a package of yarn and also that it is not twisted or untwisted while handling.

(*b*) *Plied Yarns.*—The twist in plied yarns shall be determined as in Paragraph (*a*) with the following exceptions: The jaws shall be set 10 in. apart and a tension equal to the weight of 100 yd. of yarn shall be applied. The twist of the shipment shall be the average of 40 tests taken at 10 continuous lengths of each of four strands.

Fat Content

13. (*a*) *Free Fat.*—Three 10-g. samples (approximate) shall be extracted separately in a Soxhlet apparatus for 20 extractions with alcohol-free ethyl ether (Note). In the bottom of the Soxhlet apparatus there shall be lightly placed a thin layer of cotton, previously extracted with ethyl ether, as a filter covering the opening of the siphon tube. The ether then shall be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is free fat.

NOTE.—C.p. carbon tetrachloride shall be substituted for ethyl ether for Code work.

(*b*) *Soap Fat.*—The samples from which the free fat has been removed (Paragraph (*a*)) shall be extracted in a Soxhlet apparatus for 12 extractions with neutral 95 per cent alcohol. The alcohol shall then be evaporated from the extract. After adding 25 to 30 ml. of 0.1 N HCl this shall be boiled and cooled. The solution shall then be shaken with an equal volume of neutral ether and decanted. This shall be repeated twice. The three ether extracts shall be combined and washed once by shaking with an equal volume of distilled water and then decanted. The ether shall then be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is soap fat.

(*c*) *Weight, Oven-Dry Extracted Wool.*—The extracted wool (Paragraph (*b*)) shall be dried to constant weight at 220 to 230 F. (105 to 110 C.).

(*d*) *Calculations.*—The percentage of free fat and of soap fat may be calculated on a dry or a standard regain basis by the following formulas:

$$\text{Free Fat (dry basis), per cent} = \frac{F \times 100}{W + F + S}$$

$$\text{Soap Fat (dry basis), per cent} = \frac{S \times 100}{W + F + S}$$

$$\text{Free Fat (standard regain basis), per cent} = \frac{F \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

$$\text{Soap Fat (standard regain basis), per cent} = \frac{S \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

where F = the weight of free fat
S = the weight of soap fat
W = the weight of oven-dry extracted wool

(*e*) Three samples shall be tested from each case or beam of yarn. If the three determinations do not check, or if the average results fail to conform to the specification requirements, three additional samples shall be tested from the same case or beam from which the original samples were taken.

Regain Determination

14. (*a*) Three samples of not less than 200 g. each shall be selected and weighed at the same time and under the same conditions as the bulk of the yarn which the samples represent. These samples shall then be placed in a conditioning oven at a temperature of 220 to 230 F. (105 to 110 C.). When no change in weight is noted in three consecutive weighings at 10-min. intervals, the yarn shall be considered "oven dry."

(*b*) The difference between the average of the original (initial) weights of the sample and the average of the oven-dry weights of the same shall be considered as the "moisture loss."

(*c*) The percentage regain equals the moisture loss multiplied by 100 and divided by the average oven-dry weight.

TENTATIVE METHODS OF TESTING AND TOLERANCES

FOR

WORSTED YARNS[1]

A.S.T.M. Designation: D 404 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S Broad St., Philadelphia, Pa.

ISSUED, 1934; REVISED, 1935.[2]

Scope

1. These methods of testing and tolerances apply to single or plied worsted yarns of any of the following two types:

Dry Spun Yarn, made from dry combed tops;
Oil Spun Yarn, made from oil combed tops.

Materials and Workmanship

2. The yarn shall be reasonably clean and free from slubs and shall be reasonably uniform in diameter in view of the purpose for which it is to be used.

Packing and Marking

3. Each case, beam, or other package of yarn shall be plainly marked with the name of the vendor, the net and gross weights, and some means of identifying the contract under which it was delivered.

Rejection

4. Yarn may be rejected if it fails to meet any of the requirements specified. In case of rejection, the vendor must be notified within 10 days of the shipment.

Definitions

5. (*a*) *Yarn Number.*—The number of a worsted yarn shall be the number of thousands of yards per pound (Typp System).[3]

(*b*) *Direction of Twist.*—The direction of twist shall be as defined in the Tentative Definitions and Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 35 T) of the American Society for Testing Materials, as follows:

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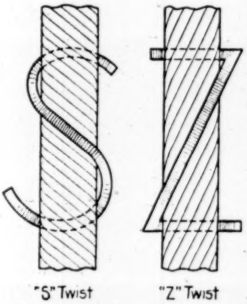
[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee D-13 on Textile Materials.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

[3] See the Yarn Number Conversion Table which appears as Appendix II, of the volume of "A.S.T.M. Standards on Textile Materials," p. 199; available as a separate publication, October, 1935; also appended to the 1935 Report of Committee D-13 on Textile Materials, see p. 452.

Twist, Direction of.—A yarn or cord has "S" twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and "Z" twist if the spirals conform in slope to the central portion of the letter "Z."



(*c*) *Standard Regain.*—The standard regain for worsted yarn shall be 15 per cent for dry spun and 13 per cent for oil spun, which is equivalent to 13.04 per cent and 11.5 per cent moisture content, respectively.

(*d*) *Standard Condition.*—Standard condition of worsted yarn shall be that reached by the yarn in equilibrium with an atmosphere having a relative humidity of 65 per cent ± 2 per cent at 70 to 80 F. (21 to 27 C.).

(*e*) *Moisture Equilibrium.*—It shall be considered that moisture equilibrium is reached when two successive weighings not less than 15 min. apart show not more than 1.0 per cent change in weight.

TOLERANCES

Tolerances

6. Tolerances shall be the limits within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract.

7. Worsted yarns shall conform to the following tolerances. Where averages are used the number of tests must be reported and the standard deviation or some other method of dispersion indicated.

(*a*) *Weight.*—The net weight of the shipment of yarn shall be calculated to the basis of standard regain.

(*b*) *Yarn Number.*—The average yarn number shall be as specified within the following permissible variations:

		PERMISSIBLE VARIATIONS
Single Yarns	Coarser than No. 12	±5 per cent
	Nos. 12 to 17	±3.5 per cent
	Nos. 17 to 23	±3 per cent
	No. 23 and finer	±2 5 per cent
Plied Yarns		±2.5 per cent

(*c*) *Twist.*—The average twist of yarn from all of the packages tested shall not vary more than ±7½ per cent from the specified twist. The average twist of yarn from any one package shall not vary more than ±7½ per cent from the average for any other package in the shipment.

(*d*) *Direction of Twist.*—The direction of twist shall be as specified.

(*e*) *Breaking Strength.*—The breaking strength of yarn shall be not less than that specified.

(*f*) *Fat Content.*—Dry spun yarns shall contain not more than 1½ per cent of fat, and oil spun yarns not more than 4 per cent of fat.

METHODS OF TESTING

Sampling

8. (*a*) Samples shall be so selected as to be fairly representative of the shipment.

(*b*) For yarn on cones, spools, or bobbins, seven cones, spools, or bobbins shall be selected from each case of yarn.

(*c*) For yarn on beams each beam of yarn shall be tested separately.

Preparation of Skeins

9. Standard skeins of 120 yd. shall be prepared by winding the yarn on a reel having a perimeter of 1½ yd. Care must be used to maintain uniform tension. The yarn shall make one full turn around single guides or pass straight through double guides. It is preferable to equip yarn reels with motors.

Yarn Number

10. Standard skeins shall be weighed to an accuracy of 0.25 per cent and the yarn number calculated. The yarn number shall be the arithmetical mean of the results.

Breaking Strength

11. (*a*) *Skein Method.*—A conditioned skein shall be broken on an approved type of testing machine. The drums of the machine shall be cylindrical spools not less than 1 in. in diameter and width, at least one of which shall be free to turn on its axis. The speed of the pulling drum when running free shall be 12 in. ± ½ in. per minute. The average skein breaking strength shall be the arithmetical mean of the results.

(*b*) *Single Strand Method.*—A conditioned single strand shall be broken on an approved type of testing machine, with jaws set 10 in. apart. The speed of the pulling jaw when running free shall be 12 in. ± ½ in. per minute. The average single strand breaking strength shall be the arithmetical mean of the results.

Twist

12. (*a*) *Single Yarns.*—The first 2 yd. of any package of yarn shall be discarded. The yarn, drawn just taut enough to prevent sagging, shall be

clamped in a twist counter with jaws set 4 in. apart. One jaw shall be rotated until the twist is removed as indicated by passing a sharp pointed needle from jaw to jaw. Not more than ½ in. of yarn shall be left out between individual tests. The twist of a shipment shall be the average of 80 tests taken at 20 continuous lengths of each of four strands. Care must be taken that the yarn is drawn from the side of a package of yarn and also that it is not twisted or untwisted while handling.

(*b*) *Plied Yarns.*—The twist of plied yarns shall be determined as in Paragraph (*a*) with the following exceptions: The jaws shall be set 10 in. apart and a tension equal to the weight of 100 yd. of yarn shall be applied. The twist of the shipment shall be the average of 40 tests taken at 10 continuous lengths of each of four strands.

Fat Content

13. (*a*) *Free Fat.*—Three 10-g. samples (approximate) shall be extracted separately in a Soxhlet apparatus for 20 extractions with alcohol-free ethyl ether (Note). In the bottom of the Soxhlet apparatus there shall be lightly placed a thin layer of cotton, previously extracted with ethyl ether, as a filter covering the opening of the siphon tube. The ether then shall be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is free fat.

NOTE.—C.p. carbon tetrachloride shall be substituted for ethyl ether for Code work.

(*b*) *Soap Fat.*—The samples from which the free fat has been removed (Paragraph (*a*)) shall be extracted in a Soxhlet apparatus for 12 extractions with neutral 95 per cent alcohol. The alcohol shall then be evaporated from the extract. After adding 25 to 30 ml. of 0.1 N HCl this shall be boiled and cooled. The solution shall then be shaken with an equal volume of neutral ether and decanted. This shall be repeated twice. The three ether extracts shall be combined and washed once by shaking with an equal volume of distilled water and then decanted. The ether shall then be evaporated from the extract and the residue dried to constant weight at 212 to 221 F. (100 to 105 C.). This residue is soap fat.

(*c*) *Weight, Oven-Dry Extracted Wool.*—The extracted wool (Paragraph (*b*)) shall be dried to constant weight at 220 to 230 F. (105 to 110 C.).

(*d*) *Calculations.*—The percentage of free fat and of soap fat may be calculated on a dry or a standard regain basis by the following formulas:

$$\text{Free Fat (dry basis), per cent} = \frac{F \times 100}{W + F + S}$$

$$\text{Soap Fat (dry basis), per cent} = \frac{S \times 100}{W + F + S}$$

$$\text{Free Fat (standard regain basis), per cent} = \frac{F \times 100}{\dfrac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

$$\text{Soap Fat (standard regain basis), per cent} = \frac{S \times 100}{\frac{100 + \text{standard regain}}{100} \times (W + F + S)}$$

where F = the weight of free fat
S = the weight of soap fat
W = the weight of oven-dry extracted wool

(*e*) Three samples shall be tested from each case or beam of yarn. If the three determinations do not check, or if the average results fail to conform to the specification requirements, three additional samples shall be tested from the same case or beam from which the original samples were taken.

Regain Determination

14. (*a*) Three samples of not less than 200 g. each shall be selected and weighed at the same time and under the same conditions as the bulk of the yarn which the samples represent. These samples shall then be placed in a conditioning oven at a temperature of 220 to 230 F. (104 to 110 C.). When no change in weight is noted in three consecutive weighings at 10-min. intervals, the yarn shall be considered "oven dry."

(*b*) The difference between the average of the original (initial) weights of the sample and the average of the oven-dry weights of the same shall be considered as the "moisture loss."

(*c*) The percentage regain equals the moisture loss multiplied by 100 and divided by the average oven-dry weight.

TENTATIVE DEFINITIONS AND TERMS RELATING TO TEXTILE MATERIALS[1]

A.S.T.M. Designation: D 123 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued as Tentative, 1921; Adopted in Amended Form, 1927; Revised, 1930; Reissued as Tentative, 1933; Revised, 1934, 1935.

Abacá.—See Fibers, Vegetable.

African Sisal.—Under Fibers, Vegetable, see Sisal.

Airplane Fabric (Cotton).—A plain-weave fabric well woven, practically without imperfections, of mercerized two-ply yarns, width 36 to 56 in., maximum weight 4.5 oz. per sq. yd., and threads per inch warp and filling 80 to 84.

Ambari.—Under Fibers, Vegetable, see Kenáf.

Asbestos Roving.—Asbestos roving is composed of a mixture of chrysotile asbestos and cotton or other vegetable fiber.

Reinforced Asbestos Roving.—Reinforced asbestos roving is composed of a core of cotton yarn covered with a mixture of chrysotile asbestos and vegetable fiber.

Asbestos Yarn.—Yarn consisting of: (1) asbestos fiber; (2) asbestos and vegetable fibers; (3) asbestos and vegetable fibers and wire; or (4) asbestos and vegetable fibers with an insert of cotton or other yarn reinforcement.

Plain Asbestos Yarn.—Yarn consisting of: (1) asbestos fiber, or (2) asbestos and vegetable fibers.

Metallic Asbestos Yarn.—Yarn consisting of plain asbestos yarn twisted with brass, copper or other fine wire. It is also termed "wire-inserted yarn."

Bad Casts (Raw Silk).—Abruptly thickened places on the threads due to the cocoon filament not being properly attached to the thread, or made by adding more than one cocoon filament at a time.

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[1] Under the standardization procedure of the Society, these definitions are under the jursidiction of the A.S.T.M. Committee D-13 on Textile Materials.

These tentative definitions comprise a revision and combination of the former Standard Definitions of Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 30) and Tentative Definitions of Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 30 T), which definitions were accordingly discontinued in 1933.

Bagging.—A very heavy loosely woven fabric used for bale tares, etc., woven from heavy tight-twisted roving, consisting largely of reworked and waste fibers. Also known as "gunny."

Bahama Sisal.—Under Fibers, Vegetable, see Sisal.

Benares Sunn.—Under Fibers, Vegetable, see Sunn.

Bimlipatam Jute.—Under Fibers, Vegetable, see Kenáf.

Binder Twine.—A somewhat stiff, single strand yarn, 3 to 4 mm. in diameter, made of hard fibers (henequen, sisal, abacá, or phormium), used chiefly for binding bundles of grain, etc.

Boiled-Off Silk.—Silk with the gum (sericin) removed.

Bombay Aloe.—Under Fibers, Vegetable, see Cantara and Piteira.

Book-Fold.—The fabric is doubled selvage to selvage, then folded back and forth upon itself in predetermined lengths. When the piece is completed, the fold-edges on each side are folded to the center and the piece is folded once more upon itself so that the fold-edges are inside, forming a compact package as long as one-half the width of the goods.

Broken Pick.—A streak across the width of the fabric caused by a completely or partially missing pick.

Brown Hemp.—Under Fibers, Vegetable, see Sunn.

Burlap (Jute).—A coarse, heavy, plain-weave fabric of coarse single yarn.

Cable Twist.—A twine, cord, or rope construction in which each successive twist is in the opposite direction to the preceding twist.

Cantala.—See Fibers, Vegetable

Cellulose-Acetate Rayon.—See Fibers, Artificial.

China Grass.—See Fibers, Vegetable.

China Hemp.—Under Fibers, Vegetable, see Hemp.

Chingma.—See Fibers, Vegetable.

Cockled or Cockling.—A curliness or crimpiness appearing in fabrics when different sizes of yarn or varying tensions on the yarns are accidentally introduced.

Coir.—See Fibers, Vegetable.

Cordage Fibers.—See Fibers, Cordage.

Corkscrews (Raw Silk).—A place in the thread in which one or more cocoon filaments are longer than the remainder and give the appearance of a spiral form.

Heavy Corkscrews (Raw Silk).—Corkscrews which are more than twice the diameter of the thread.

Corkscrew Twist.—A place in the yarn or cord where an uneven twist gives a corkscrew-like appearance.

Cotton.—See Fibers, Vegetable.

Crimp.—The difference in distance between two points on a yarn as it lies in a fabric and the same two points when the yarn has been removed from the fabric and straightened, expressed as a percentage of the distance between the two points as the yarn lies in the fabric.

Cuprammonium Rayon.—See Fibers, Artificial.

Cut (Asbestos).—A term indicating the number of an asbestos yarn. The word "cut" preceded by a number indicates, in multiples of 100 yd., the yardage per pound of single-ply yarn. For example, "5 cut" indicates that a pound of single-ply yarn so designated measures approximately 500 yd.; "10 cut" indicates a yarn that measures approximately 1000 yd. per lb.

(Woolen).—See Yarn Number (Woolen—Cut).

Da or Dha.—Under Fibers, Vegetable, see Kenáf.

Daisee Jute.—Under Fibers, Vegetable, see Jute.

Defective Splice.—A splice having irregular final twist, untrimmed ends, or excessive thickness or thinness.

Denier.—A unit of weight (0.05 g.) used to express the number of silk and rayon yarns. The weight in units of 0.05 g. of a 450-m. skein at standard conditions is the denier of silk and rayon (exclusive of spun silk and staple rayon) yarn. It is also equal numerically to the weight in grams of a 9000-m. skein at standard conditions.

Dungaree (Cotton).—A heavy cloth woven in the 2/1 twill weave from dyed warp and filling yarns, in narrow widths, usually 28 in.; approximate number of threads per inch, warp 68 and filling 52; yarn number both warp and filling 20's.

End.—An individual warp yarn.

Fell Jackets.—See Jackets.

Fiber.—A slender, elongated filament, such as rayon, silk, or wool; or a single elongated cell, like cotton or kapok; or a slender strand composed of aggregations of elongated cells like flax, jute and sisal.

Fibers, Artificial:

Cellulose-Acetate Rayon.—Filaments composed of an acetic ester of cellulose which has been coagulated or solidified from its solution.

Cuprammonium Rayon.—Filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose in ammoniacal copper oxide.

Nitrocellulose Rayon (Chardonnet).—Filaments composed of a regenerated or denitrated cellulose which has been coagulated or solidified from a solution of nitrated cellulose.

Viscose Rayon.—Filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose xanthate.

Fibers, Cordage.—Coarse hard fibers, such as abacá, sisal, henequen, cantala, phormium, palma and piteira (see Fibers, Vegetable), used in the manufacture of ropes and coarse twines. Generally too coarse and stiff to be woven into fabrics.

Fibers, Hard or Leaf.—Rather stiff elongated strands from leaves like sisal, henequen, and piteira (see Fibers, Vegetable), or leaf stems like abacá, used chiefly in coarse twines, ropes and heavy cordage.

Fibers, Soft or Bast.—Flexible elongated strands from the inner bark of plants like flax, hemp, jute and ramie, used in twines, nets and woven fabrics.

Fibers, Textile.—Slender filaments or strands that cling together, enabling them to be spun into yarns of appreciable strength and sufficiently pliable to be woven or knitted into fabrics. Essential requisites are tensile strength, length of at least 5 mm. and more than 100 times the diameter, pliability and cohesiveness; desirable, but not essential, properties are elasticity, fineness, uniformity, durability and luster. Textile fibers include cotton, flax, jute, and many other fibers of vegetable origin; silk, wool and various hairs of animal origin; rayon and allied synthetic or artificial fibers; and asbestos of mineral origin.

Fibers, Vegetable:

Abacá (a-ba-ká).—A hard fiber, rather coarse, firm texture, cream-white to brown in color, 150 to 350 cm. long, strong and durable from the leaf stems forming the trunk of the abacá plant, *Musa textilis*, cultivated in the Philippine Islands, Sumatra, Java and Borneo; used in ropes and coarse twines and cordage, especially marine cordage, oil-well cables, and binder twine. Called "Manila hemp" in the market, but quite unlike true hemp, also called "Cebu hemp" and "Davao hemp."

Cantala.—A hard fiber, finer, softer and weaker than sisal, yellow-white to brownish white, 75 to 150 cm. long, from leaves of the cantala plant, *Agave cantala*, cultivated in the Philippine Islands, Java, Sumatra and India; used in coarse twines including binder twine. Called "Manila maguey" and "Cebu maguey" in market quotations for water-retted, hand-cleaned cantala of the Philippine Islands.

Fibers, Vegetable (Continued):

China Grass.—Ramie fiber separated from the stalk and the thin outer bark, but not degummed; the form in which it is usually exported from China.

Chingma (Ching′-mah).—A rather coarse soft fiber, usually flaggy and fuzzy, straw-white, from the inner bark of the chingma plant, *Abutilon theophrasti*, cultivated in northern China and Japan. Called "China jute" and "Tientsin jute," but it is not a true jute.

Coir.—A hard fiber, usually brown, 10 to 25 cm. long, from the outer husk of the cocoanut, *Cocos nucifera*, produced chiefly in Ceylon and southern India; used in door mats and as a stuffing fiber in upholstery.

Cotton.—Fine, one-celled, twisted fibers, white or in some types tawny, brown or green, 20 to 50 mm. long, growing on the seeds of several different species of the genus *Gossypium*; used more than all other vegetable fibers, and for a wider range of purposes including yarns, twines, woven and knit goods, upholstery stuffing and packing.

American short-staple upland cotton.—Fiber 20 to 27 mm. long, from *Gossypium hirsutum*, cultivated in the southern part of the United States and introduced into nearly all cotton-growing countries.

American long-staple upland cotton.—28 to 40 mm. long, from selected varieties of *Gossypium hirsutum*, cultivated largely in the Yazoo-Mississippi delta. Also called "delta cotton."

Arizona Egyptian cotton.—Fiber 35 to 45 mm. long, from modified forms of *Gossypium barbadense*, cultivated in Arizona and southern California, includes "Pima cotton."

Egyptian cotton.—Fiber 30 to 40 mm. long, white or in some varieties light brown, from modified forms of *Gossypium barbadense*, cultivated chiefly in lower Egypt, includes "Sakellarides," "Zagora," etc.

India cotton.—Short staple, 18 to 25 mm. long, from *Gossypium neglectum*, cultivated in India.

Levant cotton.—Short staple, 18 to 25 mm. long, from *Gossypium herbaceum*, cultivated in Asia Minor and countries bordering the Mediterranean Sea.

Fibers, Vegetable (Continued):

Rough Peruvian cotton.—A rather harsh, wiry cotton, from *Gossypium peruvianum*, cultivated in Peru, used chiefly for mixing with wool.

Sea island cotton.—Fine fiber, 30 to 50 mm. long, from *Gossypium barbadense*, cultivated chiefly in the West Indies, used in the finest cotton yarns.

Flax.—A soft, fine fiber, dark gray, bluish green, brown or cream white, 40 to 100 cm. long, from the inner bark of the fiber flax plant, *Linum usitatissimum*, cultivated chiefly in northern Europe; used in linen thread, shoe thread, seine twine, sacking twine, laces, table linen, handkerchiefs, towels and in all true linens.

Courtrai flax.—Flax fiber of superior quality, very carefully prepared from straw retted in the River Lys, or most of it in recent years tank-retted in the vicinity of Courtrai, Belgium.

Dew-retted flax (Slanetz of Russia).—Flax fiber prepared by spreading the plants on the ground and exposing to the weather for retting.

Flax tow.—Short or tangled fiber beaten out in scutching—often called scutching tow; or combed out in hackling and called machine tow; used in flax yarns and twines. (This flax tow is distinctly different from upholstery flax tow.)

Flemish flax.—Flax produced in Flanders (northeastern France and Belgium).

Hackled flax (also called "dressed flax" or "dressed line").—Flax fiber, which after being scutched, has been cleaned further by combing over hackles.

Irish flax.—Flax fiber produced in northern Ireland, mostly retted in bogs, yielding a very strong fiber.

Risten (*R* in market quotations).—The standard grade of flax on which other grades of the Baltic countries are based.

Water-retted flax (Motchenetz of Russia).—Flax fiber, light cream-white to gray in color, prepared by retting the plants in water.

Fibers, Vegetable (Continued):

Hemp.—A soft fiber, dark steel gray to cream-white, usually in narrow flat ribbons, 100 to 250 cm. long, from the inner bark of the hemp plant, *Cannabis sativa*, cultivated in Italy, Soviet Republic, Yugoslavia, Hungary, China, Japan, Chile, Wisconsin, Illinois and Kentucky; used in America in commercial twines, marlines, halyards and tarred rigging.

Hemp line.—Hemp fiber, scutched and prepared so that the fibers lie straight and parallel.

Hemp tow.—Short or tangled hemp fiber, beaten out in scutching the long fiber, or hemp fiber produced from short or tangled stalks.

Italian hemp.—Hemp fiber produced in Italy, mostly water-retted and well prepared and graded.

Kentucky rough prime.—The best quality of Kentucky dew-retted hemp, broken on hand brakes, but not hackled.

Kentucky single-dressed.—Kentucky hemp further prepared by drawing it over a coarse hackle.

Russian hemp.—Hemp fiber chiefly dew-retted and prepared by hand in the Soviet Republic.

Wisconsin hemp.—Hemp fiber produced in Wisconsin by dew-retting and breaking and scutching by machinery.

Henequen (hen-e-ken′).—A hard fiber, rather coarse, of firm texture, light yellow or sometimes reddish yellow, cylindrical, 75 to 150 cm. long, from the leaves of the henequen plant, *Agave fourcroydos*, cultivated in the Yucatan peninsula, and in Tamaulipas in Mexico and in Cuba; used chiefly in binder twine and in other coarse twines and small ropes.

Istle (eest′-ley).—Hard fibers, light yellow, 20 to 50 cm. long, cylindrical and stiff, from the leaves of two closely related species of *Agave*, growing without cultivation in Mexico, used chiefly in brushes, and to a less extent in twines; used in Mexico for handmade twines and coarse sacks. Also called "Tampico" and "Mexican Fiber."

Jute.—Soft fibers, light yellow to nearly white or bright copper to deep slate, changing in age to dingy brown or gray, 100 to 500 cm. long, averaging about 240 cm. exclusive of butts.

Fibers, Vegetable (Continued):

Jute (Continued):

from the inner bark of the round-pod jute, *Corchorus capsularis*, and the long-pod jute, *Corchorus olitorius*, cultivated in India, chiefly in Bengal, and to a very limited extent elsewhere in southern Asia and in tropical Africa; used in twines, gunnies, burlaps, hessians, carpet yarns, sacks for sugar, coffee, grain, feed, fertilizer and wool, and backing for linoleum and oilcloths.

Jute butts.—The flaggy lower ends of jute fiber, 10 to 25 cm. long, cut off in preparing jute for market, used in twines and coarse bagging, especially in covering for bales of cotton.

Daisee jute (also spelled *desi* and *deshi*, meaning "local").—Fiber of long-pod jute, *Corchorus olitorius*, grown in the brackish soils in the region of Calcutta, generally ranging from copper brown to slate gray.

Tossa jute.—Fiber of long-pod jute, *Corchorus olitorius*, grown on uplands in eastern India; pearl gray to deep slate color or copper brown.

Kapok.—Stuffing fiber, composed of single cells 20 to 30 mm. long, white gray or tawny in color, produced in the seed pods of the kapok tree, *Ceiba pentandra*, and closely allied species of the bombax family, resistant to the absorption of moisture, resilient and buoyant; used as stuffing in pillows, mattresses and life preservers and for temperature and sound insulation.

Kenáf.—A soft jute-like fiber, light yellow to gray, flaggy at base, 150 to 250 cm. long, from the inner bark of the kenáf plant, *Hibiscus cannabinus*, cultivated most extensively in Persia and Trans-Caspian Russia. Called "Da" in French West Africa, "Gombo" in Portuguese Africa, "Ambari" and "Deccan Hemp" in India, "Bimlipatam" in Madras Presidency; used in twines and for purposes similar to jute.

Mescal Maguey.—A hard fiber, light straw-yellow, slightly finer and softer than sisal, 80 to 150 cm. long, from leaves of the mescal maguey plant, *Agave pseudotequilana*, cultivated in western Mexico; used in twines and cordage.

Fibers, Vegetable (Continued).

Palma.—A hard fiber nearly white or light brownish yellow, often with some coarser dark brown curved ends, 25 to 50 cm. long, from the leaves of a tree yucca, *Samuela carnerosana*, growing on high mountains in northern Mexico; used for twines, especially "paper twines." Also called "palma istle," but quite unlike istle fibers.

Phormium (for′-mi-um).—A hard fiber, reddish yellow or nearly white, finer and softer than abacá, 150 to 300 cm. long, from the leaves of the harakeke lily, *Phormium tenax*, growing wild and cultivated in New Zealand, and cultivated in St. Helena; used chiefly in hard fiber twines, including binder twine. Called "New Zealand hemp" and "New Zealand flax" but the fiber is unlike hemp or flax.

Piteira (pe-ter′-a).—A hard fiber, nearly white, and finer and softer than other hard fibers as it is prepared in Mauritius, 150 to 250 cm. long, from the leaves of the giant cabuya, *Furcraea gigantea*, native in eastern Brazil and cultivated in Mauritius, India and Natal; used chiefly for mixing with other fibers to improve the color of ropes. Called "Mauritius hemp," but it is not a true hemp and is produced in other countries besides Mauritius.

Ramie.—A soft fiber, parchment-like, light yellow or greenish and stiff in the form called "China grass," white, soft and slightly coarser than flax when degummed and bleached, very strong and durable, from the inner bark of the ramie plant, *Boehmeria nivea*, cultivated in China and Japan; used in China for dress goods and "grass cloth," in Japan for seine twine and mosquito nets and in Germany for shoe thread, trimmings, tapestries, and various woven fabrics. Also called "rhea."

Sisal.—A hard fiber, of firm texture, light yellow or nearly white sometimes slightly green, very strong and durable, 100 to 180 cm. long, from the leaves of the sisal plant, *Agave sisalana*, native in Yucatan, cultivated in East Africa, Java, Sumatra, Haiti and the Bahamas; used in hard fiber twines including binder twine and also in coarse cordage.

Bahama Sisal.—Retted in sea water and cleaned by hand; is finer, softer, weaker and lacking in luster.

Fibers, Vegetable (Continued):

Sunn.—A soft fiber, gray or brown with a wide range of color and quality due to differences in preparation, 50 to 150 cm. long, from the inner bark of the sunn plant, *Crotalaria juncea*, cultivated in India; used in twines. Also called "Sunn hemp," "India hemp," "Bombay hemp," "Brown hemp," and various sorts by the names "Benares," "Itarsi," "Jubbulpore," "Madras" and "Sewnee."

Filament.—A fine fiber or fibril.

Flax.—See Fibers, Vegetable.

Float (Defect).—A place in the fabric where warp or filling threads extend unbound over threads with which they should be interlaced.

Gage.—A measure of the fineness of knit fabric as determined by the closeness of the wales, that is, the longitudinal rows of loops. It is expressed by the number of wales or needles in one and one half inches.

NOTE.—The word "gage" is also used as an expression of thickness.

Gombo Hemp.—Under Fibers, Vegetable, see Kenáf.

Grenadine Yarn (Silk).—A yarn composed of more than one strand, each individual strand of which has been doubled with a reverse twist, each twist having a minimum of approximately the following number of turns per inch depending on the number of strands used:

STRANDS	MINIMUM NUMBER OF TURNS
2 ($\frac{13}{15}$ denier or equivalent)	32
3	30
4	28

NOTE.—When more than 4 strands are used, the minimum number of turns is decreased in accordance with the above proportion.

Hairiness (Raw Silk).—The condition of the thread when there are numerous loose ends of cocoon filaments projecting from the thread.

Hawser Twist (Cotton).—A twine, cord or rope construction in which the first and second twists are in the same direction and the third twist in the opposite direction.

Heavy Corkscrews.—See Corkscrews.

Heavy Goods.—Name applied in Calcutta quotations to material called "sacking" in the United States.

Hemp.—See Fibers, Vegetable.

Henequen.—See Fibers, Vegetable.

Hessians.—Name applied in United Kingdom, India, and on the Continent to material called "burlap" in the United States.

Holland Finish (Cotton).—A glazed or unglazed finish, consisting of oil and a filling material, applied to cotton fabrics to make them opaque or semi-opaque; resembles a beetled linen fabric formerly known as "Holland."

Indian Hemp.—Under Fibers, Vegetable, see Sunn.

Istle.—See Fibers, Vegetable.

Italian Hemp.—Under Fibers, Vegetable, see Hemp.

Jackets (woven or felted).—A textile product, woven or pressed into tubular or sleeve form, ready for covering and shrinking on a machine roll.

Jubbulpore Hemp.—Under Fibers, Vegetable, see Sunn.

Jute.—See Fibers, Vegetable.

Jute Butts.—See Fibers, Vegetable.

Kapok.—See Fibers, Vegetable.

Kenáf.—See Fibers, Vegetable.

Kink (fabric).—A place in the fabric where a slack strand has twisted on itself, forming a loop in the yarn or cord.

Knot.—A joining by tying of threads together.

Long Knots (Raw Silk).—Knots which have loose ends from 3 to 25 mm. ($\frac{1}{8}$ to 1 in.) in length.

Very Long Knots (Raw Silk).—Knots which have loose ends exceeding 25 mm. (1 in.) in length.

Laid Fabric (Cotton).—A fabric made without filling yarn, the parallel warp yarns being held together by means of rubber latex or other binding material.

Lea (Cotton).—A 120-yd. skein of yarn containing 80 turns, that is, each $1\frac{1}{2}$ yd. in length.

(Linen).—See Yarn Number (Linen).

Linen.—Under Fibers, Vegetable, see Flax.

Loop-Knot.—A snarl or curl produced by a filling yarn coiling upon itself.

Loops (Raw Silk).—Small open places in the thread due to the excessive length of one or more cocoon filaments.

Long Loops.—Loops which exceed 1 cm. ($\frac{1}{2}$ in.) in length.

Long Knot.—See Knot.

Maguey.—Under Fibers, Vegetable, see Cantala and Mescal Maguey.

Manila Hemp.—Under Fibers, Vegetable, see Abacá.

Mauritius Hemp.—Under Fibers, Vegetable, see Piteira.

Mescal Maguey.—See Fibers, Vegetable.

Metallic Asbestos Yarn.—See Asbestos Yarn.

Mexican Fiber.—Under Fibers, Vegetable, see Istle.

Mexican Sisal.—Under Fibers, Vegetable, see Henequen.

Mispick.—A pick not properly interlaced.

Moisture Content (Moisture, Percentage of Moisture).—The moisture present in a textile material expressed as a percentage of the original weight as determined by definite prescribed methods.

Moisture-Free Weight.—The weight of a textile material determined after drying to constant weight by definite prescribed methods.

Moisture Regain.—The moisture present in a textile material expressed as a percentage of the moisture-free weight, as determined by definite prescribed methods.

Natal Hemp.—Under Fibers, Vegetable, see Piteira.

Neatness (Raw Silk).—An expression of the degree of freedom of the raw silk thread from loops, nibs, and hairiness as defined.

New Zealand Flax.—Under Fibers, Vegetable, see Phormium.

Nibs (Raw Silk).—Small thickened places less than 3 mm. ($\frac{1}{8}$ in.) in length.

Nitrocellulose Rayon.—See Fibers, Artificial.

Number of Yarn.—See Yarn Number.

Off-Square.—The difference between the percentage of warp crimp and the percentage of filling crimp.

Organzine Yarn.—Two or more raw silk strands twisted in the singles, doubled and twisted in the reverse direction in the ply. Turns per inch in the singles and ply usually within the limits of 10 to 20 turns; generally used as warp.

Palma.—See Fibers, Vegetable.

Philippine Maguey.—Under Fibers, Vegetable, see Cantala.

Phormium.—See Fibers, Vegetable.

Pick.—An individual filling yarn.

Piteira.—See Fibers, Vegetable.

Plain Weave.—A fabric pattern in which each yarn of the filling passes alternately over and under a yarn of warp and each yarn of the warp passes alternately over and under a yarn of the filling.

Ramie.—See Fibers, Vegetable.

Raw Silk.—Silk as it has been reeled from the cocoon.

Rayon.—A generic term for filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice, and solidifying it in the form of a filament.

NOTE.—Rayon as commercially manufactured is produced by four different processes. The resulting rayons from each process while similar in appearance differ amongst themselves and with each other to a more or less degree according to the differences in their physical and chemical properties. The different type rayons are known as follows:

(*a*) Nitrocellulose Rayon (Chardonnet)
(*b*) Viscose Rayon
(*c*) Cuprammonium Rayon
(*d*) Cellulose-Acetate Rayon

Reed Marks.—Marks or lines warpwise of the cloth, usually caused by too many or too few warp yarns being drawn into a dent, a faulty setting of the loom, or imperfections in the reed.

Regain.—See Moisture Regain.

Reinforced Asbestos Roving.—See Asbestos Roving.

Run (Woolen).—See Yarn Number (Woolen Run).

Russian Hemp.—Under Fibers, Vegetable, see Hemp.

Sewed Yarn.—A yarn in the fabric interwoven by hand.

Shoe-Fold.—The fabric is folded from both ends into twelve or sixteen folds to the piece, the length of the fold depending upon the length of the piece.

Sisal.—See Fibers, Vegetable.

Size.—See Yarn Number.

Slub.—See Slug (General).

Slug (Raw Silk).—A thickened place several times the diameter of the thread, 3 mm. ($\frac{1}{8}$ in.) or over in length.

Long or Large Slug (Raw Silk).—A slug which exceeds 1 cm. ($\frac{1}{2}$ in.) in length or which is very much larger in diameter than the thread.

(General).—An abruptly thickened place in the yarn or a bunch of lint entangled in the yarn, cord, or fabric.

Smash.—A place in the fabric where a number of warp yarns or cords have been broken, usually due to the shuttle getting caught in the shed during weaving, or to faulty harness motion.

Spun Rayon.—Yarn made from cut rayon filaments, the cut filaments being twisted and drawn out into a yarn by usual spinning processes.

Spun Silk.—Silk yarn consisting of short filaments obtained from silk wastes spun in a similar manner to worsted yarn.

Standard Atmosphere (Textiles).—Air maintained at a relative humidity of 65 per cent at 70 F.

Standard Moisture Regain.—An arbitrary figure formally adopted for the regain of any specific textile material to be used in calculating the standard weights of shipments or deliveries of textiles.

Standard Weight.—The moisture-free weight of a textile material plus the weight corresponding to its standard moisture regain.

Sunn.—See Fibers, Vegetable.

Tampico Fiber.—Under Fibers, Vegetable, see Istle.

Thick and Thin Places (Major Defects).—Places in the fabric where for 1 in. or more the count varies more than a specified percentage from the specified count.

(Minor Defects).—Places in the fabric where for less than 1 in. the count varies more than a specified percentage from the specified count.

Thread (Silk).—The ply of yarns is sometimes referred to as the number of thread, as 2 thread for a 2 ply.

Thrown Silk.—Raw silk that has been twisted, or doubled and twisted.

Tientsin Jute.—Under Fibers, Vegetable, see Chingma.

Tire Builder Fabric.—A fabric consisting of hawser cord yarn in the warp with single yarn filling at intervals to keep the warp threads together.

Tossa Jute.—Under Fibers, Vegetable, see Jute.

Tram Yarn (Silk).—Raw silk threads doubled and twisted with a low number of turns per inch, generally used as filling.

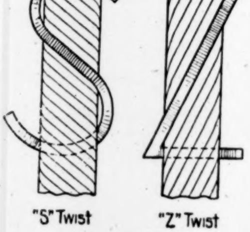
Tula Istle.—Under Fibers, Vegetable, see Istle.

Twill Weave.—A weave which produces pronounced lines running diagonally across the fabric.

Warp Face Twill.—A twill weave in which the warp threads produce the diagonal effect.

Twine (Not Binder Twine).—A cord made up of two or more yarns of medium twist with ply twist in the opposite direction.

Twist, Direction of.—A yarn or cord has "S" twist if, when held in a vertical position, the spirals conform in slope to the central portion of the letter "S," and "Z" twist if the spirals conform in slope to the central portion of the letter "Z."



Viscose Rayon.—See Fibers, Artificial.

Webbing, Elastic.—A strong narrow fabric made with rubber threads as part of warp or filling or of both.

Wrong Draw.—A defect in a fabric due to the warp and filling not interlacing in accordance with the prescribed weave or design and caused when one or more warp yarns have been drawn through the wrong harness.

Yarn.—An assemblage of fibers or filaments of animal, mineral, or vegetable origin, alone or in combination, either natural or manufactured, twisted or laid together to form a strand or group of strands for use in weaving, knitting, or forming in any manner into textile materials.

Yarn Number (Asbestos).—See Cut (Asbestos).

(Cotton).—The number of 840-yd. hanks contained in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions. The number of folded or plied yarns is that of the single yarn from which they are spun.

(Jute).—The weight in pounds of a spindle of 14,400 yd. of yarn at standard conditions expressed as "pounds per spindle."

(Linen).—The number of 300-yd. hanks contained in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions. The number of folded or plied yarns is that of the single yarn from which they are spun. Also known as "lea."

(Raw Silk).—See Denier.

(Rayon).—See Denier.

(Spun Rayon).—The number of 840-yd. hanks contained in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions. The number of folded or plied yarns is that of the single yarn from which they are spun.

(Spun Silk).—The number of 840-yd. hanks contained in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions. The number of folded or plied yarns is that of the finished yarn.

(Woolen--Cut).—The number of 300-yd. "cuts" or hanks in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions.

(Woolen—Run).—The number of 1600-yd. hanks in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions.

(Woolen and Worsted--Typp System).—The number of a woolen or worsted yarn shall be the number of thousands of yards per pound.

(Worsted).—The number of 560-yd. hanks in 1 lb. avoirdupois (7000 grains) of the yarn at standard conditions. The number of folded or plied yarns is that of the single yarn from which they are spun.

Yarn Size.—See Yarn Number.

TENTATIVE SPECIFICATIONS
FOR
ROUND-HOLE SCREENS FOR TESTING PURPOSES[1]

A.S.T.M. Designation: E 17 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

Issued, 1935.[2]

Scope

1. These specifications cover testing screens for use in the classification of materials according to size in all cases where specifications call for use of screens having circular openings.

Plates

2. Plates used in the manufacture of screens shall be made of brass, bronze, steel or other rigid metal. Thickness of plates shall be governed by size of openings as well as screening area of screens and shall conform to the following requirements:

Screening Area, sq. in.	Diameter of Opening, in.	Thickness of Plate, in. Minimum	Thickness of Plate, in. Maximum
Under 100	all sizes	0.049	0.066
100 and over	$\frac{1}{16}$ and $\frac{1}{8}$	0.049	0.066
	$\frac{1}{4}$ to $2\frac{1}{2}$	0.060	0.100
	3 and $3\frac{1}{2}$	0.075	0.130
	4 and 5	0.105	0.160
	6 and 8	0.120	0.175

Type of Frame

3. Frames for laboratory screens shall be at least 8 in. in diameter. Frames for standard 8-in. laboratory screens shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.[3] Frames for large screens may be of either hard wood or metal and may be square, rectangular or circular, as specified. For screens having circular openings 1 in. in diameter or larger, frames larger than 8 in. in diameter are recommended.

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[1] Under the standardization procedure of the Society, these specifications are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

These Tentative Specifications are in effect a **proposed** revision of, and are intended to supersede when adopted as standard, the present Standard Specifications for Round-Hole Screens for Testing Purposes (A.S.T.M. Designation: E 17 - 33), 1933 Book of A.S.T.M. Standards, Part II, p. 1242.

[2] **Accepted for publication as tentative by Committee E-10 on Standards, August 22, 1935.**

[3] 1933 Book of A.S.T.M. Standards, Part II, p. 1244.

Spacing of Opening

4. (*a*) Spacing of openings for all screens shall conform to the following requirements:

Nominal Diameter of Opening, in.	Nominal Width of Metal Between Adjacent Openings, in.
$\frac{1}{16}$	$\frac{3}{64}$
$\frac{1}{8}$	$\frac{3}{32}$
$\frac{1}{4}$	$\frac{1}{8}$
$\frac{3}{8}$	$\frac{3}{16}$
$\frac{1}{2}$	$\frac{3}{16}$
$\frac{5}{8}$	$\frac{3}{16}$
$\frac{3}{4}$	$\frac{1}{4}$
$\frac{7}{8}$	$\frac{1}{4}$
1	$\frac{3}{8}$
$1\frac{1}{4}$	$\frac{3}{8}$
$1\frac{1}{2}$	$\frac{1}{2}$
2	$\frac{5}{8}$
$2\frac{1}{2}$	$\frac{3}{4}$
3	$\frac{3}{4}$
$3\frac{1}{2}$	$\frac{3}{4}$
4	$\frac{3}{4}$
5	1
6	1
8	1

(*b*) The openings shall be so arranged that their centers lie at the vertices of triangles which are approximately equilateral within the limits given by the permissible variations in width of metal and diameter of opening.

(*c*) For screens having openings $\frac{1}{4}$ in. or less in diameter, the actual diameter of any opening shall not vary from the nominal diameter more than 5 per cent.

(*d*) For screens having openings over $\frac{1}{4}$ in. in diameter, the actual diameter of any opening shall not vary from the nominal diameter more than 3 per cent.

(*e*) The width of metal between adjacent openings in the screen plate shall not vary from the nominal value given in Paragraph (*a*) more than 20 per cent.

TENTATIVE METHOD OF TEST
FOR
LONG-TIME (CREEP) HIGH-TEMPERATURE TENSION TESTS OF METALLIC MATERIALS[1]

A.S.T.M. Designation: E 22 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1933; REVISED, 1934, 1935.

Scope

1. (*a*) This method covers long-time (creep) high-temperature tension tests of metals within the range from room temperature to 2000 F.

(*b*) Long-time tension tests are made at those elevated temperatures where creep effects assume technical or engineering importance. The ranges of temperature usually investigated are as follows:

	TEMPERATURE RANGE, DEG. FAHR.
Carbon steels	550 to 1100
Low alloy steels (less than 8 per cent alloy content)	550 to 1200
High alloy steels (non-austenitic)	750 to 1400
High alloy steels (austenitic[a] and semi-austenitic)	750 to 1800
Nickel-chromium and high nickel-chromium-iron alloys	900 to 2000
Copper and aluminum alloys	200 to 800

[a] Under austenitic alloys are included those alloys wholly austenitic, austenitic-ferritic, and those which may change from originally an austenitic structure to some other conditions not definitely known.

(*c*) Testing temperatures shall be established at points that are multiples of 50 on the Fahrenheit scale, or equivalents on the Centigrade scale. It is recognized that for special purposes, tests at other temperatures may be desirable to establish the creep characteristics.

Selection of Metals for Test

2. This method presupposes agreement upon the selection of suitable samples for test specimens to meet the requirements of individual applications.

NOTE.—In the testing of some materials it is customary and often necessary to subject the specimens to a stabilizing treatment. If such is done, it shall be reported fully in the recorded data.

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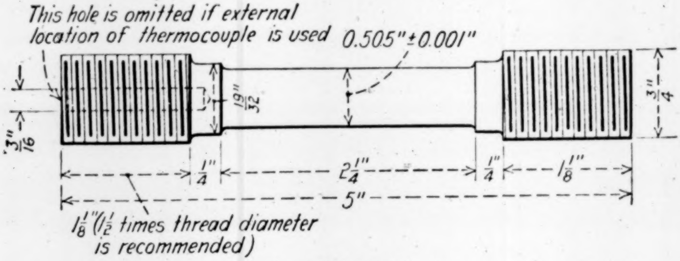
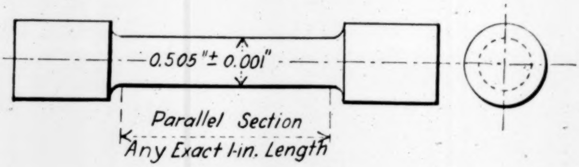
[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the Joint A.S.M.E. - A.S.T.M. Research Committee on Effect of Temperature on the Properties of Metals.

Test Specimens

3. (*a*) Test specimens may be of either of the types shown in Fig. 1 (*a*) or (*b*). The diameter of the test specimen shall preferably be 0.505 in. ± 0.001 in. In cases where small diameter is imperative, specimens having a diameter of 0.357 in. or 0.252 in. may be used, but the gage length shall be not less than 2 in. The diameter of the reduced section of the specimen between base of fillets shall not vary by more than ±0.0005 in. The surface shall be machined smooth and free from tool marks or scratches, and finished with No. 00 emery cloth.


This hole is omitted if external location of thermocouple is used
0.505"±0.001"
19"/32
3"/16
3"/4
1"/4
2 1"/4
1"/4
1 1"/8
5"
1 1"/8 (1 1/2 times thread diameter is recommended)

(*a*) Specimen with threaded ends.


0.505"± 0.001"
Parallel Section
Any Exact 1-in. Length

(*b*) Specimen with blank ends.

FIG. 1.—Test Specimens for High-Temperature Tension Tests.

(*b*) In the case of Fig. 1 (*a*), the ends of the specimen shall be threaded, at least ¾ in. in diameter for the 0.505-in. specimen, ½ in. in diameter for the 0.357-in. specimen, and ⅜ in. in diameter for the 0.252-in. specimen, and shall be machined true and axial.

(*c*) A sketch showing the specimen used shall accompany the report of test results.

Testing Machine

4. (*a*) The type of testing machine to be used in long-time (creep) high-temperature tests is not specified, but shall be reported with the results of a series of tests. The applied load shall be calibrated to an accuracy within ±1 per cent. Precaution shall be taken to avoid excessive inertial and frictional effects in the loading mechanism.

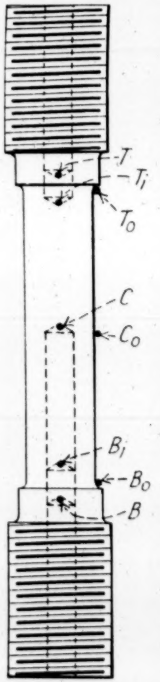


FIG. 2.

Location of Thermocouples

T *Inside top end beyond fillet*
T_1 *Inside top end at or within fillet*
T_0 *Outside top end at fillet*
C *Inside at center of length*
C_0 *Outside at center of length*
B *Inside bottom end beyond fillet*
B_i *Inside bottom end at or within fillet*
B_0 *Outside bottom end at fillet*

	Nominal Test Temperature, deg. Fahr.									
T										
T_1										
T_0										
C										
C_0										
B										
B_r										
B_0										

FORM I.—Form for Reporting Temperature Survey of Furnace.

The above form on letter size sheets suitable for recording test data is available in pads of 25 sheets at 50 cents per pad; 3 pads, $1.00. Address, American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

(*b*) Precautions shall be taken to insure that the testing load is axially applied. Each specimen when set up for test shall be inspected for faulty alignment in the machine. Eccentricity of loading can often be detected by elastic extension measurements taken at room temperature before commencing the test. Apparatus provided with extensometers affording measurements on opposite sides will reveal unsatisfactory alignment when unequal strain is shown by the opposite readings. Elongation measuring devices which show extension on one side of the specimen only do not readily lend themselves to the detection of eccentric loading.

(*c*) *Shackles.*—The type of shackles used to obtain axial loading are not specified, but a detailed description of the shackles used shall be reported with the results of a series of tests.

NOTE.—It is to be noted that eccentricity of loading of the specimen may be lessened by using rods or wire cables of the greatest length possible to connect the shackles to the heads of the testing machine.

Furnace and Heating

5. (*a*) A drawing showing the furnace and heating element in detail shall be submitted with the results of a series of tests.

(*b*) For specimens with 2-in. to 5-in. gage length, the design of the furnace shall be such that the maximum variation of temperature over the gage length of the specimen shall not exceed ±3 F. for temperatures up to and including 1200 F., ±5 F. for temperatures over 1200 F. and up to and including 1600 F., and ±10 F. for temperatures over 1600 F. For all longer gage lengths, the design of the furnace shall be such that the maximum variation of temperature over the gage length of the specimen shall not give rise to an error in strength in excess of 1 per cent.

NOTE.—It should be noted that the transverse dimensions of the furnace should be as small as possible, merely large enough to allow for the shackles and extensometer. Any suitable arrangement of the heating element that will result in the required uniformity of temperature is considered satisfactory. It may be noted that equalization of temperature over the length of the test specimen may be improved by a metallic lining inside the furnace tube, or by the use of multiple heating coils. Liquid baths may be used at lower temperatures provided that no reaction of the liquid upon the test metal occurs. Oil is suitable at lower temperatures. No definite recommendations are made as to the length of the furnace, provided the required uniformity of temperature is realized. Reference to the various publications of the Joint Research Committee is suggested for guidance.

Temperature Measuring Apparatus

6. (*a*) Temperature measurements shall be made by means of suitable thermocouples and potentiometer or millivoltmeter equipment, which shall be accurate to within the following permissible variations for the temperature ranges shown:

	PERMISSIBLE VARIATIONS
Up to and including 1200 F.	± 3 F.
Over 1200 to and including 1600 F.	± 5 F.
Over 1600 F.	± 10 F.

(*b*) The hot junction of the thermocouple shall be located at any one of the locations T, T_o, C_o, B_o, B shown in Fig. 2, and the location of the junction shall be reported with the results of tests. Where external contact is made between thermocouple bead and the specimen, the thermocouple shall be shielded in like manner in the creep tests and in the calibration.

Temperature Survey of Furnace

7. (*a*) A survey of the temperature distribution throughout the test specimens shall be made before making a series of tests of specimens of a given metal, on each furnace and test shackle arrangement used. This survey shall be made using a special calibration bar, shown in Fig. 2, and for each series of tests the calibration bar shall be of the same dimensions, and shall be of the same type chemical composition, as the test specimens to be used. A survey of temperature distribution shall be made for each temperature at which specimens are to be tested, and detailed results of these surveys shall be reported with the results of specimen tests. These surveys furnish data for the comparison of specimen temperature at the point where the thermocouple is applied in routine tests of specimens with the temperature of the test specimen at the middle of the reduced section of the test specimen on the axis of the specimen (C, Fig. 2). The temperature of the calibration bar shall be also determined at the other points indicated in Fig. 2.

(*b*) During a survey of temperature distribution on a calibration, all temperature readings shall be taken as nearly simultaneously as possible.

(*c*) Testing temperature as normally measured during the course of a test shall be corrected, if necessary, using the survey data as a basis of correction. The amount of correction applied shall be the difference between the temperature as normally measured and that found to be the average shown by the survey couples imbedded at the required points.

Room Temperature During Tests

8. During the period of time required for survey tests the range of room temperature shall not exceed 10 F. During creep tests, the room temperature shall be kept as constant as possible, and all

elongation measurements shall be taken when the variation in room temperature does not exceed 10 F. During all tests the equipment shall be shielded from abnormal drafts.

Strain Measurement During Test

9. There shall be reported with the results of all tests, the construction details of the strain measuring apparatus used. Scale divisions on the extensometer shall not be larger than 0.0001 in. per inch of gage length. It is preferable that the extensometer be attached to the gage length of the specimen, or that suitable optical means bearing directly on the gage length of the specimen be used.

Sustained Loads

10. The constant-temperature, constant-stress method shall be employed. Tests shall be made on individual specimens at such loads in round hundreds or thousands of pounds per square inch, suitable to the material and temperatures, and tests shall be made in such number and for such time periods as to achieve the desired object.

Test Procedure

11. The following procedure shall be observed in all tests:

(*a*) It is recommended that not more than one specimen be placed in a furnace at one time, and that each furnace be provided with its own individual control.

(*b*) Before heating, the specimen shall be loaded to check alignment. (See Section 4 (*b*).)

(*c*) During heating to the temperature desired, the test specimen shall not sustain a unit load in excess of 250 lb. per sq. in.

(*d*) The heating period preparatory to loading shall be long enough to establish thermal equilibrium and shall be reported. The load shall then be applied without sudden jolt to the specimen.

(*e*) The immediate elongation in gage length upon application of load shall be observed and reported.

(*f*) Further elongation observations shall be made after intervals of 8 hr., 24 hr., 48 hr., and each 24-hr., 48-hr., or other necessary periods thereafter until the completion of the constant-temperature, constant-stress run. Time intervals shall be such that all characteristics of the elongation will be observed.

(*g*) When the testing of a specimen that is not ruptured is to be discontinued, the elastic recovery or contraction of the gage length upon removal of load shall be observed, before allowing the specimen to cool and this shall be reported.

(*h*) All specimens tested shall be carefully preserved for six months for further studies as to their hardness, microstructure, impact resistance, etc., should such be desired.

FORM II.—FORM FOR REPORTING DATA AND RESULTS OF LONG-TIME (CREEP) HIGH-TEMPERATURE TENSION TESTS.

Test Laboratory ....

Material .... Specimen No. ....

Test Temperature .... Original Stress ....

Location of thermocouple ....

Sensitivity of elongation measuring device ....

Time allowed for equilibrium before loading ....hr. ....min

Temperature fluctuation of specimen ....deg. Fahr.

Temperature fluctuation of room ....deg. Fahr.

Total elongation, loaded ....in.

Creep rate over test period ....per cent

Creep rate during secondary period ....per cent

Immediate extension upon application of load ....in.

Contraction upon removal of load ....in.

Original gage length, room temperature ....in.

Gage length after test, room temperature ....in.

Change in gage length, room temperature ....in.

ELONGATION

Date	Hours Duration	Total Inches	Inches per Inch	Increment, in. per Inch	Remarks

The above form on letter size sheets suitable for recording test data is available in pads of 25 sheets at 50 cents per pad; 3 pads, $1.00. Address, American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.

(*i*) Measurements of gage length shall be made at room temperature before placing the specimen in, and after removing the specimen from the furnace and reported.

Recording and Reporting of Data

12. A uniform system of recording and reporting of data shall be used. The accompanying forms for recording and reporting shall be used so that results from cooperating laboratories may be readily compared.

(*a*) *Reporting Temperature Surveys.*—For reporting the results of the temperature distribution surveys, Form I is recommended.

(*b*) *Reporting Test Data.*—Form II shall be used for reporting the data and results of long-time (creep) high-temperature tests. The data required on Form II are sufficient for completing the time-creep curves and for evaluating creep rates. Under the column "Remarks" shall be noted the increases in stress, temperature fluctuations, etc.

(*c*) *Time-Creep Curves.*—For plotting time-creep curves[1] the following scales shall be used:

SCALE FOR TIME (ABSCISSAS)	SCALE FOR CREEP (ORDINATES)
1 in. = 100 hr.	½ in. = 0.001 in. for creep rates of 1 per cent in 10,000 hr.
1 in. = 100 hr.	½ in. = 0.0001 in. for creep rates of 0.1 per cent in 10,000 hr.

(*d*) *Summary of Data.*—In reporting results of long-time high-temperature tension tests full information about material, apparatus and tests methods shall be reported, as follows:

Materials.—The report shall include the following information concerning the materials tested:

Process of manufacture and whether material is rolled, forged or cast.

Complete chemical analysis.

Complete details of heat treatment.

Physical properties of the material at room temperature.

Size of sample from which specimens were cut.

Relative location and direction of specimen. (Illustrate with sketch.)

If material was removed from service, complete details of service conditions shall be given.

Micro-structure and deep etch of samples.

Test Methods.—The report shall include the following information concerning the apparatus and methods of testing:

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[1] Dietzgen No. 340–10 or equivalent cross-section paper is recommended for this purpose.

Description of apparatus, shackles used, method of calibrating loading mechanism and accuracy of loading.

Description of temperature control-recording arrangement.

Description of furnace.

Description of elongation measuring device.

Radical departures, if any, from recommended procedure and technique.

Sketch of specimen used.

Results of temperature surveys of furnace, Form I (see Paragraph (*a*)).

Test data required on Form II (see Paragraph (*b*)).

Time-creep curves (see Paragraph (*c*)).

A supplementary Appendix appears on the next page.

APPENDIX

The Tentative Method of Test for Long-Time (Creep) High-Temperature Tension Tests of Metallic Materials (E 22 - 34 T) provides for the presentation of the fundamental data, that is, the time-creep values, in tabular form and as time-creep curves. All matters dealing with evaluation or interpretation of the data have been omitted from the test method. Evaluation and interpretation of the data will naturally vary depending on the specific application to engineering design. The Joint Research Committee feels that a useful purpose will be served by including in this Appendix a brief description of the more recognized practices.

PART I.—PREPARATION FROM TIME-CREEP CURVES OF STRESS-RATE OF CREEP AND STRESS-TEMPERATURE CURVES—INITIAL CREEP NEGLECTED

The first step in the usual evaluation and presentation of creep-test data is the preparation from the time-elongation curves of stress-rate curves in which, for each test temperature, the stress is plotted *versus* the rate of creep produced in the so-called second stages. Some laboratories prefer to plot both stress and rate logarithmically[1] while some prefer to plot the stress to cartesian coordinates.[2]

It is assumed in this evaluation that the rate of creep in the so-called secondary flow period becomes approximately constant after an initial period, the duration of which varies with different materials, temperatures, and applied stresses. It should not be assumed that these rates continue constant for indefinite periods as would be required for extended extrapolations.

The rate of creep is then taken as the slope of the time-creep curve over the latter portion of the test period.

Rates of creep for a number of applied stresses at each test temperature are then plotted to give a stress-rate curve for each temperature. The plotting procedure varies with different laboratories as indicated above.

These stress-rate of creep curves may then be used to prepare stress-temperature curves by scaling off the stresses at various temperatures which produce arbitrarily chosen rates of creep such as 0.0000001 in. per in. per hr. (0.1 per cent in 10,000 hr.) 0.000001 in. per in. per hr. (1.0 per cent in 10,000 hr.) or any other rates which may be of particular interest.

Such a method of evaluation does not take into consideration the magnitude of initial creep which occurs when the stress is applied or subsequent creep at a diminishing rate prior to the so-called secondary flow period in which a constant rate of creep is assumed. Omission of this initial creep may make evaluation of creep test data by the above noted methods very misleading in instances where the amount of permissible total deformation during the useful life of equipment to be operated at elevated temperatures is limited.

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[1] F. H. Norton, "The Creep of Steels at Elevated Temperatures," 1929.
C. L. Clark and A. E. White, "Influence of Recrystallization Temperature and Grain Size on the Creep Characteristics of Non-Ferrous Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 32, Part II, p. 492 (1932).

[2] H. J. Tapsell, "Creep of Metals," Oxford University Press, London (1931).
H. C. Cross and E. R. Johnson, "Creep Properties of 5 per cent Chromium, 0.50 per cent Molybdenum Steel Still Tubes," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 80 (1934).

PART II.—PREPARATION FROM TIME-CREEP CURVES OF STRESS-RATE OF CREEP AND STRESS-TEMPERATURE CURVES—INITIAL CREEP CONSIDERED

There are several methods used in evaluation of creep test data in which the total deformation or the initial creep as well as the secondary flow rates are considered.

The most conservative although probably the least accurate method uses, as the average rate of creep, a value obtained by dividing the total creep at the end of the test period (expressed either in inches per inch or per cent) by the duration of the test period (hours, days, etc.).

A second method determines the slope of the time-creep curve over an arbitrarily chosen period during the secondary flow period, and the projection of this slope back to zero time gives the initial deformation which resulted before the time-creep curves assumed an approximately constant rate. The total deformation over any time period may then be computed as the initial deformation plus the product of the rate of creep during the secondary flow period and the desired duration of time.

The total deformation for any time period may also be obtained by extrapolation from the portion of the secondary flow period of the time-creep curve over which the rate of creep is determined.

It should not be assumed that these rates continue constant for very long periods as would be required for extended extrapolations.

A third method uses logarithmic time-creep charts to obtain the values of stress *versus* time for given amounts of total deformation such as 0.001, 0.01, and 0.1 in. per in. (0.1, 1.0 and 10 per cent), which in turn are plotted on a semi-logarithmic graphs and may be interpolated for stresses yielding 0.001 in. per in. (0.1 per cent) for 10,000 hr., 0.1 in. per in. (1.0 per cent) for 10,000 hr., etc.

PART III.—RECOGNITION OF IMPORTANCE OF TOTAL STRAIN AND THE RELAXATION PROBLEM

In comparing stresses corresponding to specified creep rates, some engineers contend that reference should be made to the total creep which has occurred previous to the attainment of the specified rate. This is a necessary requirement for the application of creep data to other service than constant stress. Some authorities go so far as to say that the stress to give a specified rate is completely determined by the total strain regardless of time so that rates corresponding to applied stresses depend only on the amount of previous creep regardless of the rapidity of its application. The necessity of considering initial creep is universally admitted although the sufficiency of total creep to determine completely the relation between stress and rate is not universally accepted.

In all applications involving relaxation or relief of stress the initial creep is attained more rapidly than with a constant stress test. Test methods are based on the progressive relief of elastic strain either smoothly or in steps to equal the total creep. Until the degree of correspondence between constant stress and constant total strain (or so-called relaxation tests) is more definitely known, step down tests or relaxation tests will be preferred by many engineers in determining the suitability of materials for application where creep automatically causes relief of stress. In the conduct of such tests it is understood that where apparatus constructed to maintain constant total strain is not used, the applied loads shall be reduced periodically in the amounts required to prevent the total elastic plus plastic strain exceeding a predetermined and specified amount which may be any one of the following values: 1 mil per in., 2 mils per in., 5 mils per in., 1 per cent, etc.

PART IV.—CONSIDERATION OF ALLOWABLE DEFORMATIONS IN EXPECTED USEFUL LIFE OF EQUIPMENT AND PREPARATION OF STRESS-STRAIN CHARTS

For many design applications, the approximate service temperature, allowable deformation and expected useful life of the material are known. The problem is to choose a stress to meet these conditions. By dividing the allowable deformation by the useful life an average creep rate is obtained, but this rate does not correspond to the rate purporting to represent any particular combination of stress and temperature. This discrepancy makes it necessary to consider initial deformation and various expedients for bridging the unavoidable gap between test conditions and service conditions.

Since it is practically impossible to avoid interpolation and extrapolation it is convenient to replace the actual creep curve by its final tangent or asymptote. The slope of this straight line is exactly the same as the "creep rate" usually measured. By projecting this line back to zero time, a convenient measure of the "initial deformation" is obtained. The intercept and slope of this line determine its position and permit the best available estimate of the total creep at the end of any time longer than the test. The use of a creep rate alone without an intercept implies that the creep curve may be represented by a straight line *through the origin*, which assumption is not supported by test data.

If tests are made at a few different stresses at the same temperature, the initial deformation and minimum creep rate are obtainable from each. These values may be plotted as functions of the applied stress.[1,2] If the material is known to be reasonably stable, these curves may be extended to zero stress by the assumption that stress is necessary to produce creep. This gives a convenient method of interpolation between stresses. From these curves it is possible to estimate the total creep at the end of any time by adding the initial deformation to the product of the creep rate for the same stress by the time.

The most convenient method of presenting these data is in the form of a stress-strain chart in which the estimates of total creep at the end of several periods of time are plotted for each of several stresses. By connecting points representing the same time for various stresses, a family of stress-strain curves is obtained. This chart shows the relation among the three variables—allowable deformation, useful life and stress at the testing temperature *in so far as these relations are obtainable from the original creep data.* From such a chart, the stress which may be expected to meet the imposed conditions of allowable deformation and service life may be chosen without further computation.

Similar charts at other temperatures allow the plotting of curves to show stress-temperature relations for any desired combination of life and allowable deformation. The construction of these charts from conventional creep curves is not difficult and they offer a convenient source of design information.

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[1] P. G. McVetty, "Working Stresses for High Temperature Service," *Mechanical Engineer*, March, 1934, p. 149.

[2] P. G. McVetty, "The Interpretation of Creep Tests," *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part II, p. 105 (1934).

TENTATIVE METHODS OF VERIFICATION OF TESTING MACHINES[1]

A.S.T.M. Designation: E 4 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED AS TENTATIVE 1923; ADOPTED IN AMENDED FORM, 1924;
REVISED, 1927; REISSUED AS TENTATIVE, 1933; REVISED, 1934, 1935.[2]

DEFINITIONS

1. (*a*) *Testing Machine.*—A mechanical device for applying a load (force) to a specimen.

NOTE.—Usually the magnitude of the load can be changed at the will of the operator. Many testing machines are arranged to measure the load, but this is not always the case, especially with impact machines and machines for testing ductility.

(*b*) *Error.*—In the case of a testing machine, the value obtained by subtracting the correct value of the quantity measured (usually load) from the indicated value as given by the testing machine.

NOTE.—The error may be positive or negative.

(*c*) *Percentage of Error.*—In the case of a testing machine, the ratio expressed as a percentage of the error to the correct value of the quantity measured.

(*d*) *Correction.*—In the case of a testing machine, the value obtained by subtracting the indicated value from the correct value of the quantity measured.

NOTE.—The correction has the same magnitude as the error but the opposite sign. It is recommended that, except for special cases, no corrections be used on machines tested and found to have errors within the tolerances given in these methods.

(*e*) *Tolerance.*—In the case of a testing machine, the maximum allowable error in the value of the quantity indicated.

NOTE.—It is convenient to express tolerance in terms of percentage of error. The numerical value of the tolerance for a testing machine is so stated hereafter in these methods.

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

These methods are in effect a revision of, and replace the former Standard Methods of Verification of Testing Machines (A.S.T.M. Designation: E 4 - 27), which standard was accordingly discontinued in 1933.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

The word "accurate" applied to a testing machine shall be used without numerical values. The word "error" shall be used with numerical values. For example: "An accurate testing machine was used for the investigation"; but "At a load of 30,000 lb. the error of the testing machine was 15 lb." A testing machine is said to be accurate if the indicated load is within the specified tolerance of the actual load.

NOTE.—The *accuracy* of a testing machine should not be confused with *sensitiveness*. For example, a testing machine might be very sensitive, that is, it might indicate quickly and definitely small changes in the load, but, nevertheless, be very inaccurate. On the other hand, the accuracy of the results is, in general, limited by the sensibility.

(*f*) *Loading Range.*—The loading range of a testing machine or of an apparatus for calibrating a testing machine is the range of indicated loads for which the testing machine or the calibrating apparatus gives results within the tolerances specified.

(*g*) *Elastic Calibration Device.*—An elastic calibration device for use in verifying the load readings of a testing machine consists of an elastic member to which loads may be applied combined with a mechanism for indicating the magnitude of deformation under load.

METHODS FOR VERIFYING TESTING MACHINES THAT MEASURE LOAD

Advantages and Limitations of Different Methods

2. Four methods of verifying testing machines are listed in this standard:

(*a*) *Standard Weights.*—Verification by the direct application of standard weights to the weighing mechanism of the testing machine, where practicable, is the most accurate method. Its limitations are (*1*) the small range of load which can be covered, (*2*) the nonportability of any large amount of standard weights, and (*3*) its nonapplicability to horizontal testing machines or to vertical testing machines whose weighing mechanisms are attached to their upper platens.

(*b*) *Proving Levers.*—Verification by the use of standardized proving levers loaded with standard weights ranks second in accuracy. Its limitations are (*1*) the fact that the range of load possible with proving levers, while greater than with standard weights, is not great enough to cover the capacity range of large testing machines, and (*2*) the inconvenience of transportation of proving levers and standard weights for verifying large testing machines.

(*c*) *Elastic Calibration Device.*—Verification by the use of an elastic calibration device ranks third in accuracy. It is free from the limitations of the methods referred to in Paragraphs (*a*) and (*b*).

(*d*) *Comparison Method.*—Verification by a comparison of the tensile strength of test specimens ("companion specimens") cut from the same piece of metal, is distinctly less accurate than the three methods referred to in Paragraphs (*a*), (*b*) and (*c*), and should be used only when none of the other methods are available. If the results of a verification test by the comparison method fail to agree with the results of a verification test by any of the other three methods, the results given by the comparison method shall be discarded.

Method of Applying Load

3. In the verification of a testing machine the loads shall be applied in ascending order.

NOTE.—For any testing machine (particularly for certain types of machines in which the load-indicating device is actuated by a Bourdon pressure tube, a hydraulic (or steam-engine) indicator or other device depending on the elastic properties of a material, or for machines in which the load is measured by measuring the pressure in a hydraulic jack) the errors observed at corresponding loads taken, first by increasing the load to the test load and then by decreasing it to the test load, may not agree. Testing machines are usually used under increasing loads, but if a testing machine is to be used under decreasing loads it should be calibrated under decreasing loads as well as under increasing loads.

Selection of Test Loads

4. For any loading range, the testing machine shall be verified by at least five test loads (except for testing machines designed to measure only a smaller number of definite loads, such as certain hardness testing machines). The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

NOTE.—A testing machine may have more than one loading range. For instance, a 100,000-lb. capacity testing machine may have one loading range from 5000 lb. to 40,000 lb. and a second loading range from 55,000 lb. to 100,000 lb. Section 4 requires that the machine must be verified by at least five test loads between 5000 lb. and 40,000 lb. and also that the machine must be verified by at least five test loads between 55,000 lb. and 100,000 lb.

Eccentric Loading

5. For the purpose of determining the loading range of a testing machine all calibration loads shall be applied so that the resultant load shall be as nearly along the axis of the testing machine as is possible.

NOTE.—The effect of eccentric load on the accuracy of a testing machine may be determined by calibration readings taken with proving levers or an elastic calibration device placed so that the resultant load is applied at definite distances from the axis of the machine, and the loading range determined for a series of eccentricities. In the case of testing machines in which the load reading depends on the hydrostatic pressure in a cylinder fitted with a piston the effect of eccentricity of loading is most serious when the piston is at the extreme outward position allowable.

A. Method of Verification by Standard Weights

Method by Standard Weights

6. Standard metal weights of suitable design, finish, and adjustment shall be placed on the weighing platform of the testing machine or upon trays or other supports suspended from the load-measuring mechanism in place of the specimen. The weights shall be applied in increments and removed in the reverse order. They shall be arranged symmetrically with respect to the weighing platform, so that the center of gravity of the load lies in the vertical line through the center of the platform. The applied load and the indicated load shall be recorded for each test load applied, and the error calculated from these data.

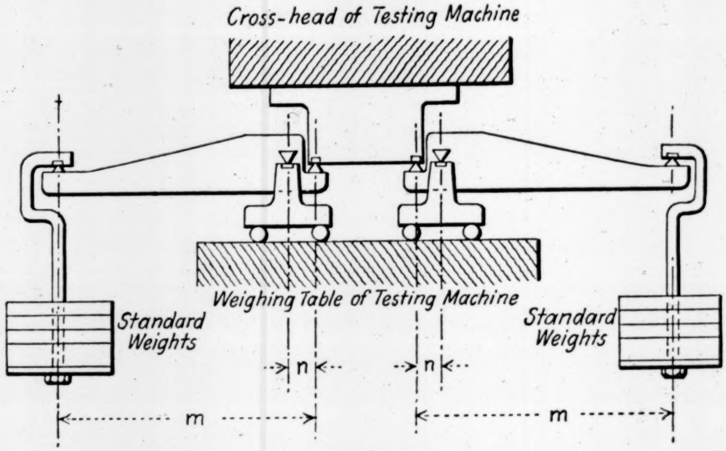
Cross-head of Testing Machine
Weighing Table of Testing Machine
Standard Weights
Standard Weights
n
n
m
m

FIG. 1.—Proving Levers.

NOTE.—The method of verification by standard weights can be used only on vertical testing machines. The total load is limited by the size of the platform and the number of weights available. Often twenty weights of 50 lb. each are used, a total of 1000 lb.

This method of verification is seldom used for any but small testing machines, as the loading range does not include the loads for which large machines are used.

B. Method of Verification by Standardized Proving Levers

Description of Levers

7. The arrangement of proving levers for verifying testing machines is shown in Fig. 1. The two levers rest on supports on the weighing platform of the testing machine. These supports shall move easily in a horizontal direction, which insures that the forces at each of the knife edges shall be very nearly vertical. The inner knife

edges in each lever bear against a suitable block in the movable head of the testing machine. Weight trays or hangers are suspended from each of the outer knife edges and these trays or hangers are loaded with standard weights. The increment of load put on the testing machine by the standard weights is the amount of standard weights multiplied by the lever ratio m/n, Fig. 1.

Specifications of Levers

8. The knife edges, as well as their supports, shall be of hardened tool steel. The knife edges shall be ground sharp to an angle of 90 deg. The load on any knife edge shall not exceed 7000 lb. per linear inch. The three knife edges in each lever shall be parallel, and their edges shall lie in a plane. Each lever shall have machined surfaces in this or in some parallel plane, upon which a spirit level can be placed.

Verification of Levers

9. The lever ratio of a proving lever shall be determined by the use of at least three test loads; the amount of weights used shall not be less than the maximum load applied upon one of the arms of a lever in using the levers to verify testing machines. The proving lever shall be balanced over its center knife edge with suitable weight trays suspended from the end knife edges. Standard weights shall then be applied to the trays in three steps, corresponding approximately to 50, 75, and 100 per cent of the weights available, and the proving lever shall then be brought to a balance by the use of small weights and by observations of the freely swinging proving lever. From the weights in the two weight trays the lever ratio shall be calculated.

Method of Procedure

10. The proving levers shall be placed symmetrically in the testing machine to be verified and both levers brought as near to a horizontal position as is feasible, after applying each increment of load, by means of the movable head of the testing machine. The testing machine shall be balanced with the levers in place and the weight trays empty. Standard weights shall be applied (or removed) in increments, half an increment in (or from) each tray. The weights shall be placed symmetrically on the weight trays, with the center of gravity of the weights over the center of the tray. The applied load and the indicated load shall be recorded for each test load applied, and the error calculated from these data.

NOTE.—The use of standardized proving levers on horizontal testing machines involves the use of bell crank levers. They require special methods of determination of lever ratio, which have not yet been codified in A.S.T.M. standards. Proving levers for vertical testing machines are now available up to 50,000-lb. capacity.

C. *Method of Verification by Means of an Elastic Calibration Device*[1]

Design and Workmanship

11. An elastic calibration device should be so designed and constructed that its accuracy is not in danger of being impaired by handling, shipping, or ordinary use, and so that parts subject to damage, replacement, or removal for storage and shipment can be replaced without impairing the accuracy of the device.

NOTE.—This section is non-quantitative in its requirements. It is placed in the method for the purpose of calling attention to the fact that an elastic calibrating device if improperly designed and constructed may, like any other delicate measuring instrument, be damaged and rendered inaccurate by handling and shipping.

Shackles and Bearing Blocks

12. An elastic calibration device shall be provided with shackles, bearing blocks, or any other necessary fixtures through which the load is to be applied to the calibration device. All such fixtures should be so designed and constructed that when placed in a testing machine in reasonably good condition there shall be no extra-tolerance variation of reading due to imperfections in the bearing blocks or in the motion of the head of the testing machine.

NOTE.—This section is non-quantitative in its requirements. It is placed in the method for the purpose of calling attention to the fact that poorly designed loading fixtures can render inaccurate the readings of an elastic calibration device.

Graduation of Scale

13. (*a*) The scale of the indicating mechanism shall be uniformly graduated. The distance between any two graduation lines, dots, or other dividing marks (or between their images, if a viewing system with a definite optical magnification is used), shall be not less than 0.035 in.

(*b*) The difference between the position of any graduation line and its correct position on the scale shall not exceed one twentieth of the distance between two adjacent graduation lines. For scales on a circular dial, when successive lines are set to one fixed index line, the positions of successive graduation lines nearly diametrically opposite, referred to another fixed index line shall differ from each other by (*1*) not more than 5 per cent of the smallest division of the dial, or (*2*) not more than 0.1 per cent of the minimum load in the loading range of the instrument, if (*2*) be larger than (*1*).

(*c*) The change of load necessary to cause a relative movement of 0.1 in. between the index line and the scale (or its image if a viewing system with a definite optical magnification is used) shall not exceed 1 per cent of the capacity load of the instrument.

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[1] The term "calibration device" shall be interpreted to include solid bars, hollow bars, elastic loops, and other members whose elastic deformation can be measured.

Label Showing Manufacturer, Number, and Capacity

14. The manufacturer's name, the capacity load, and the serial number of the device shall be legibly marked on some part of the instrument.

Temperature Equalization

15. When using an elastic calibration device to verify the load readings of a testing machine the device should be placed near, or preferably in, the testing machine a sufficient length of time before the test so that the device and the testing machine shall be at very nearly the same temperature.

Elimination of Small Temperature Effects due to Stress

16. To minimize errors due to temperature effect of stress and psuedo-elastic action, the time schedule followed when verifying an elastic device which is loaded in axial tension or compression shall be reported; and the same time schedule, within limits stated in the report, shall be followed when using the device to calibrate a testing machine.

Primary Standards for Elastic Calibration Devices

17. (*a*) For loads not exceeding 100,000 lb. an elastic calibration device shall itself be calibrated by applying dead weights known to be accurate within 0.02 per cent.

(*b*) For loads exceeding 100,000 lb. an elastic calibration device may be calibrated by another elastic calibration device or by a combination of several elastic calibration devices, or by proving levers[1] and dead weights. In this case the calibrating load applied shall be known to be accurate within 0.1 per cent.

Preliminary Cyclic Loading

18. Before taking readings for the formal verification of an elastic calibration device by means of dead weights or other primary standards, the device shall be subjected to a series of cyclic loads varying from a minimum load not greater than 2 per cent of the capacity load of the device to a maximum load not less than 5 per cent nor more than 10 per cent above the nominal capacity load.

Routine in Calibration of Elastic Calibration Device

19. For any range of test loading which may be applied in calibrating an elastic calibration device there shall be applied at least

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[1] The term "proving levers" is not to be interpreted as allowing the use of the lever system of a compound lever testing machine or of a platform scale as a part of a primary standard.

eight test loads, and the difference between any two successive test loads shall not exceed one fifth of the difference between the minimum and the maximum test loads. The series of test loads shall be applied to the elastic calibration device at least three times, and the shackles or bearing blocks shall be readjusted before each application of a series of loads.

Tolerance for Elastic Calibration Device

20. (*a*) For ordinary use the loading range of an elastic calibration device shall be that range of load within which any reading under an applied load shall not differ from the average of at least three readings under the same load by more than one fifth of 1 per cent.[1]

(*b*) The report of the verification of the elastic calibration device shall also state the loading range within which no reading varies from the average of at least three readings under the same load by more than one tenth of 1 per cent. This range shall be designated as the *Precision Loading Range* for the device.

Temperature Correction for Elastic Calibration Device

21. In using an elastic calibration device made of steel with not more than 5 per cent of alloying elements, a fairly accurate correction for variation in temperature may be made on the basis that the modulus of elasticity in tension or compression (or flexure) diminishes by 0.015 per cent for each degree Fahrenheit increase in temperature. For other metals, if the change in the modulus of elasticity with temperature is known, a correction for temperature should be applied to the readings of the instrument. During any calibration of a testing machine with an elastic calibrating device, or during the calibration of the device itself temperature shall be kept as uniform as possible.[2]

D. Verification by Companion Specimen Method

Description of Comparison Method

22. When the direct method of verification of a testing machine cannot be carried out (as is the case at present with horizontal testing machines, for example), or when an elastic calibration device is not available, a comparison method of verification may be used. In this

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[1] This means that the report of a standardizing laboratory on an elastic calibration device will state *within what loading range* it may be used, rather than reporting a blanket acceptance or rejection of the device. This follows the practice recommended for testing machines.

[2] Similar errors due to change of modulus of elasticity with temperature may be present in the load-indicating mechanism of a testing machine using a Bourdon gage or other device dependent on the elastic deformation of a member.

method the machine to be verified is tested by comparing its indications with the corresponding readings obtained under the same conditions by the use of another testing machine, especially tested and verified, as specified in Section 23. The method of verification by comparison shall be carried out by the use of a series of companion specimens, half of which are to be tested in tension in the machine to be verified, and half of which are to be tested in tension in the especially verified testing machine which serves as a standard machine. The general provisions respecting the application of the test loads and the loading range which are outlined in the direct method of verifying testing machines (Sections 3, 4 and 5) shall apply to the verification of testing machines by the comparison method, so far as is practicable.

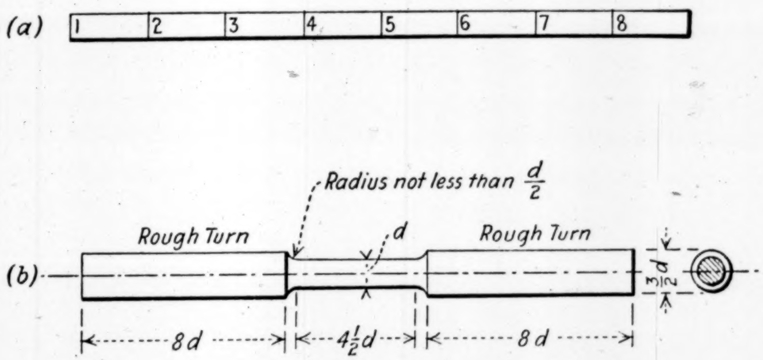

FIG. 2.—Companion Specimen.
(*a*) Method of Numbering Specimens.
(*b*) Form of Test Specimen.

Requirements for Testing Machines Used for Verifying Other Machines

23. (*a*) A testing machine which is to be used as the standard for verifying other testing machines shall itself be verified by a special test, in which the verification is carried out twice. The loading range shall be determined by the tolerance of ±1 per cent (Section 27). For the loading range established, the differences in indications found in the two tests of the standard machine shall not exceed 0.25 per cent.

(*b*) In verifying testing machines by the companion specimen method, corrections shall be applied to the indications of the standard machine and these corrections shall be based on the average correction obtained in the two tests used in its verification.

Test Specimens

24. (*a*) For each test load, eight or more tension test specimens shall be cut from soft rolled or drawn steel and numbered consecutively, as in Fig. 2 (*a*).

(*b*) The tensile strength of the steel shall be determined by a preliminary test and the sets of specimens for the comparison test shall have such nominal cross-sectional areas as will give, approximately, the loads required. The form of the specimen shall be as shown in Fig. 2 (*b*). The ends may be threaded, or otherwise machined, to fit holders, but it is recommended that those specimens shipped to another laboratory be left with cylindrical ends. The actual value of "*d*" (Fig. 2 (*b*)) for each specimen shall be determined by means of a micrometer.

NOTE.—It should be noted that the standard tension test specimen, 0.5 in. in diameter and having a 2-in. gage length, satisfies the requirements for a specimen for the verification of a testing machine by the comparison method. See Fig. 9 of the Standard Methods of Tension Testing of Metallic Materials (A.S.T.M. Designation: E 8) of the American Society for Testing Materials.[1]

Method of Procedure

25. (*a*) The specimens having odd numbers shall be tested in the machine to be verified and those having even numbers in the standard testing machine. The tensile strength only shall be determined.

(*b*) The speed of the testing machine, by which is meant the speed of the pulling head when the machine is running idle with no specimen in the machine, when testing verification specimens shall be approximately the same for both the standard testing machine and the machine being verified. The speed shall be the slowest speed that can be obtained on both machines; in any case the speed shall not exceed 1 in. per minute per inch of diameter of companion specimen.

(*c*) When testing companion specimens, especial care shall be taken to maintain the weighing beam of the testing machine in equilibrium as the tensile strength of the specimen is approached. It is recommended that a mark be placed at the middle of the trig loop and that a pointer be placed on the beam for verification tests, and that the pointer be kept as nearly on the mark as possible.

Computation of Error

26. (*a*) The average tensile strength (in pounds per square inch) of the odd-numbered specimens, multiplied by the nominal area of cross-section, shall be considered a measure of the indicated

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[1] 1933 Book of A.S.T.M. Standards, Part I, p. 949.

load, and the average tensile strength of the even-numbered specimens, multiplied by the nominal area of cross-section, shall be considered a measure of the applied load. The error shall be calculated from these data.

(*b*) If the tensile strength (in pounds per square inch) of any companion specimen varies more than 1 per cent from the mean of the group with which it is tested, its tensile strength shall not be used in computing the error of the testing machine. If more than one specimen in the odd-numbered group or more than one specimen in the even-numbered group exceeds the allowable variation in tensile strength, all the specimens shall be discarded and another set prepared.

TOLERANCES FOR TESTING MACHINES THAT MEASURE LOAD

Tolerance Within Loading Range of a Testing Machine

27. The error for loads within the loading range of a testing machine shall not exceed 1 per cent (Notes 1 and 2).

NOTE 1.—This means that the report of the verification of a testing machine will state *within what loading range it may be used*, rather than reporting a blanket acceptance or rejection of the machine.

NOTE 2.—In no case shall the loading range be stated as including loads below a value which is 100 times the smallest load which can be read on the testing machine. (This means that if a testing machine had graduations so spaced that it can be read to within $\frac{1}{10}$ division and the machine is sensitive to $\frac{1}{10}$ division it would be possible for the loading range to extend down to the load corresponding to 10 divisions. On the other hand, if the testing machine was sensitive to only 2 divisions, the loading range could not extend below the load corresponding to 200 divisions.)

Corrections

28. The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required tolerance.

TIME INTERVAL BETWEEN VERIFICATIONS

Time Interval Between Verifications

29. It is recommended that testing machines, when in constant use, be verified at intervals of six months and, when used intermittently, at intervals of two or three years. Testing machines shall, however, be verified immediately after making repairs or adjustments of the weighing mechanism, and whenever there is reason to doubt the accuracy of the results, without regard to the time interval since the last verification.

REPORTS AND CERTIFICATES

Reports

30. A clear and complete report shall be prepared of each verification of a testing machine. This report shall state the method of verification used, and shall give the serial numbers and the names of manufacturers of all apparatus used in carrying out the verification. It shall state how and by whom and when the calibration of the apparatus used in verifying the testing machine was made, the loading range, and the "precision" loading range of the calibration apparatus, and of the testing machine.

Certificates

31. A certificate giving the manufacturer's serial number and a brief description of the testing machine, the manufacturer's name, the date of verification, and the loading range, shall be signed by the person responsible for the maintenance of the testing machine, and this certificate shall be posted in plain view of a person operating the testing machine.

TENTATIVE DEFINITIONS OF TERMS RELATING TO METHODS OF TESTING[1]

A.S.T.M. Designation: E 6 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1923; REVISED, 1924, 1925, 1930, 1932, 1935.[2]

Elastic Limit.—The greatest stress which a material is capable of developing without a permanent deformation remaining upon complete release of the stress.

NOTE.—It is a matter of experience with many materials, especially with many metallic materials, that using ordinary methods of testing, the values found for elastic limit by means of observations of permanent deformation (set) after release of stress do not differ widely from the values found for proportional limit, the latter being defined as:

Proportional Limit.—The greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain (Hooke's Law).

Since the determination of proportional limit is much more readily made than is the determination of elastic limit, it is customary to accept the proportional limit as equivalent to the elastic limit for such materials, and hence the proportional limit is frequently called the "proportional elastic limit."

In certain specifications of the Society, the term "Elastic Limit" is used to designate a value obtained by a test method which does not involve the release of stress during a test, but which does involve the determination of a limiting load at which there occurs an appreciable increase in rate of strain with respect to stress. This method may determine, for some materials, a satisfactory value of the proportional elastic limit, but the property termed "Yield Strength" determined by the "set method" as described below, is felt to be a more widely satisfactory and significant measure of the desired strength property of the material.

Yield Strength.—The stress at which a material exhibits a specified limiting permanent set.

NOTE.—It is usually impracticable and probably impossible to determine the stress at which inelastic action in a member *begins*. Plastic yielding in nearly all members (including the specimen in a carefully controlled laboratory test) starts as local actions and becomes measurable only after many local internal adjustments and accommodations have occurred, and after a considerable portion of the member is affected by the yielding.

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[1] Under the standardization procedure of the Society, these definitions are under the jurisdiction of the A.S.T.M. Committee E-1 on Methods of Testing.

These definitions, when adopted, will be added to the Standard Definitions of Terms Relating to Methods of Testing (A.S.T.M. Designation: E 6 - 30), see 1933 Book of A.S.T.M. Standards, Part I or Part II, pp. 965 and 1248, respectively.

[2] Latest revision accepted by Committee E-10 on Standards, August 22, 1935.

The limit of usefulness of many materials, especially metals, in members subjected to approximately static loading at ordinary temperatures is therefore determined by a measurable value of plastic yielding of the material above which the material is considered to be damaged and below which the damaging effects are considered to be negligible.

The following methods are recommended for determining the yield strength of a material:

1. For material that has a "sharp-kneed" stress-strain diagram and hence exhibits at a certain stress the special characteristic of yielding without increase in stress. Two satisfactory methods are in use:

(*a*) "*Drop of the Beam*" *Method.*—In this method the load is applied to the specimen at a steady rate of increase and the operator keeps the beam in balance by running out the poise at approximately a steady rate. When the yield strength of the material is reached the increase of load stops, but the operator runs the poise a trifle beyond the balance position, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device, there is a sudden halt of the load-indicating pointer corresponding to the drop of the beam. The load at the "halt" or the "drop" is recorded, and the corresponding stress is taken as the yield strength. This method of determining the yield strength requires only one man to conduct a test.

(*b*) *Total Strain Method Using Dividers.*—This method is frequently called the "dividers method." In this method an observer with a pair of dividers or other suitable apparatus, watches for visible elongation between two section marks on the specimen. When visible stretch is observed, the load at that instant is noted, and the stress corresponding to the load is taken as the yield strength. For the higher strength steels, a gage length of less than 8 in. is recommended.

Note on Yield Point.—The above two methods determine what is usually called the yield point which is commonly defined as follows:

Yield Point.—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

It should be noted that only materials that exhibit this unique phenomenon of yielding have a yield point. The term yield point should not be used in connection with material whose stress-strain curve in the region of yield is a smooth curve of gradual curvature.

2. For material whose stress-strain diagram in the region of yield is a smooth curve of gradual curvature.

(*a*) *Set Method.*—This method can be used, if desired, for materials having "sharp-kneed" stress-strain diagrams, but is especially adapted to materials whose stress-strain diagram in the yield range is a smooth curve of gradual curvature.

For nearly all materials, if at any point on the stress-strain diagram such as *r* in Fig. 1, the load is released the diagram for decreasing load will follow a line, *rm*, approximately parallel to the initial portion, *OA*, of the diagram for increasing load. *Om* will then give the approximate value of the permanent set after the release of the stress *OR*. The value of this set is given in percentage of original gage length. Thus to determine the yield strength by the "set method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then with the stress-strain diagram (Fig. 1) lay off *Om* equal to the specified value of the set, and draw *mn* parallel to *OA* and thus locate *r*, the intersection of *mn* with the stress-strain diagram. Draw *Rr* parallel to the *X* axis and then *OR* gives the value of the yield strength.

In reporting values of yield strength obtained by this method, the specified value of "set" used should be stated in parentheses after the term yield strength. Thus:

Yield strength (set = 0.1 per cent) = 52,000 lb. per sq. in. indicates that at a stress of 52,000 lb. per sq. in. the approximate permanent set of the material reached the value of 0.1 per cent of the original gage length.[1]

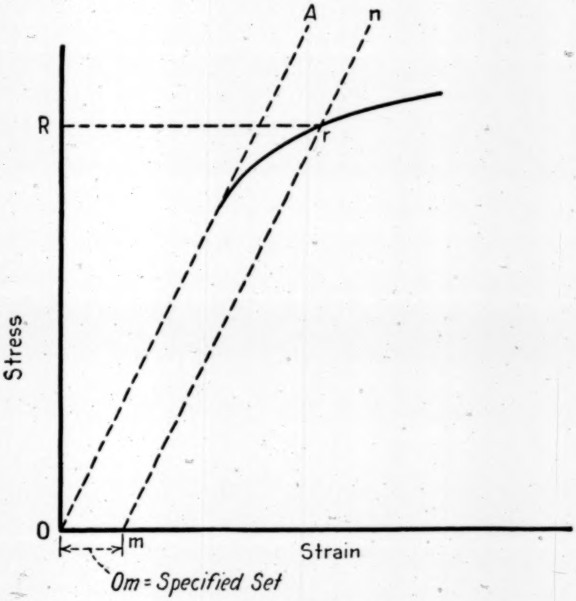

FIG. 1.—Stress-Strain Diagram.

In using this method, an extensometer reading to 0.0001 in. per inch of gage length would be sufficiently sensitive for most materials. It will be observed that the elastic limit and proportional limit are special values of the yield strength in which the specified limiting set is not measurable with the instruments used and hence is considered to be zero.

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[1] Yield Strength (or its equivalent) is specified as follows in the standards and tentative standards of the American Society for Testing Materials:

STANDARDS OR TENTATIVE STANDARDS FOR:	LIMITING VALUE OF "SET," PER CENT
Alloy-Steel Pipe	0.2
Aluminum-Alloy Bars, Rods, Shapes, Sheet	
Magnesium-Base Alloy Forgings, Castings, Sheet	
The Alloy: Copper, 80 per cent; Tin, 10 per cent; Lead, 10 per cent	0.5 (elongation under load; approximately equivalent to "set" of 0 35 per cent)
Copper-Silicon Alloy Plates, Sheets, and Bars	
Malleable Iron Castings	
Sand Castings of Alloy: Copper, 88 per cent; Tin, 8 per cent; Zinc, 4 per cent.	
Aluminum Bronze Castings	
Bronze Bearing Metals and Steam or Valve Sand Castings	
Composition Brass or Ounce Metal Sand Castings	
Naval Brass Rods for Structural Purposes	

For any given stress the deviation (offset) from Hooke's law is only approximately equal to the set after the removal of that stress, and the approximation becomes less and less exact as the permissible deviation diminishes. This method is devised for determining a stress corresponding to a well marked plastic deformation, or set, and it is not feasible to specify a very small value for the permissible "set," *Om.*

(*b*) ***Approximate Method Without Stress-Strain Diagram.***—**For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified permanent set occurs will be known within satisfactory limits; therefore, in such tests a specified total strain may be used, and the stress on the specimen, when this total strain is reached, is the value of the yield strength.** The total strain can be obtained satisfactorily by use of an extensometer reading to 0.0001 in. per inch of gage length. But it is recommended that this approximate method be used only after agreement between producer and consumer, with the understanding that check tests be made for obtaining stress-strain diagrams for use with the set method to settle any misunderstandings.

TENTATIVE RECOMMENDED PRACTICE
FOR
METALLOGRAPHIC TESTING OF FERROUS AND NON-FERROUS METALS[1]

A.S.T.M. Designation: E 3 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.

Scope

1. (*a*) The aim of metallographic testing is to reveal the constitution and structure of metals and alloys by means of the microscope, at relatively high magnification (microscopic examination) or at low magnification (macroscopic examination).

(*b*) Inasmuch as the preparation, etching and examination of the different metals varies to some extent, the metallographic examination of each metal and its alloys is discussed separately and in the following order:

METAL	SECTIONS
Iron and Steel	5 to 11
Aluminum and its Alloys	12 to 14
Copper and its Alloys	15 to 17
Lead and its Alloys	18 to 20
Magnesium and its Alloys	21 to 23
Nickel and its Alloys	24 and 25
Precious Metals	26 and 27
Tin and its Alloys	28 and 29
Zinc and its Alloys	30 to 32

GENERAL PROCEDURE FOR SELECTING, MOUNTING AND CLEANING TEST SPECIMENS

Selecting Test Specimens

2. The location of the test specimen for microscopic examination is of prime importance and may be determined by preliminary macroscopic examination. In a casting, a section cut perpendicular to the surface will

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[1] Under the standardization procedure of the Society, these methods are under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

This Recommended Practice is in effect a tentative revision of and is intended to supersede when adopted as standard the present Standard Methods of Metallographic Testing of Iron and Steel (E 3 - 24) and the Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 - 27), see 1933 Book of Standards, Part I, pp. 909, 922, respectively.

show the variations in structure from the outside to the interior. In forged or rolled metal, both transverse and longitudinal sections should be examined; a longitudinal section is generally preferable where only one section is used. Special investigations may at times require specimens parallel to the original surface of the product. A single specimen is not necessarily representative. Due care must be taken in cutting the sample not to change the structure to be examined; in steel, for instance, this may occur in shearing or torch cutting, or even in grinding hardened specimens. The location of the surface examined should always be given in reporting the results and in the description of any illustrative photomicrographs so that it will be entirely clear exactly what section of the material was used for the examination. A suitable method of indicating surface locations is shown in Fig. 1.

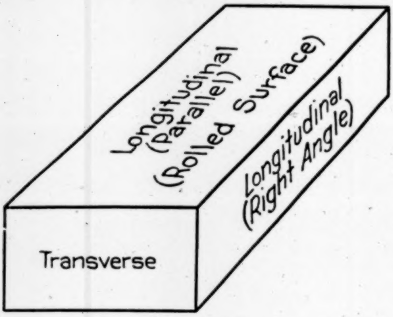

FIG. 1.—Method of Specifying Location of Area Shown in Photomicrograph.

SHAPES TO BE SAMPLED	DIRECTION OF SECTION	POSITION WITHIN OBJECT
Round Bar Wire Odd Shapes Coated Wire Case Hardened Round Bars	Longitudinal Transverse	Distance from Axis Distance from Axis
Rectangular Bars Sheet Strip Plates	Longitudinal (Parallel) Longitudinal (Right Angle) Transverse	Distance from Rolled Surface Distance from Edge Distance from Rolled Surface Distance from Edge

Mounting Test Specimens

3. (*a*) Specimens too small to be handled readily must be mounted. With sheet specimens, this is usually accomplished by binding several into a pack held together by two end pieces and two bolts; the pack should be tightly bound to prevent excessive absorption and subsequent exudation of etchants. Pores may be filled by immersing the pack in molten paraffin; separating the sheets with dense blotting paper may also eliminate this exudation (the blotting paper may become impregnated with abrasive, however, and make polishing difficult). Care should be especially exercised if hydrofluoric acid is used for etching as subsequent fuming may attack the microscope objective. The sheets to be examined are frequently alternated

with "filler" sheets of a softer alloy in order to secure a more compact specimen and to preserve surface irregularities. Other types of specimens are generally placed in a metal ring and a mounting medium cast around them. For ferrous metals the usual mounting medium is solder of 50 per cent lead and 50 per cent tin or a more fusible alloy like Wood's metal. An alloy of 52.5 per cent bismuth, 31.5 per cent lead and 16 per cent tin (melting point 95 to 98 C.) is also used in some laboratories. Cadmium-zinc eutectic (82.5 per cent cadmium, 17.5 per cent zinc; melting point 264.5 C.) has been found a useful mounting material for zinc castings, since it possesses approximately the same polishing and etching characteristics as zinc. The temperature of the eutectic should be kept below 300 C. since cadmium oxide fumes are very poisonous. Pure zinc is a good mounting material for galvanized wire. Sulfur is widely used as it has a low melting point (119 C. (246 F.)) and resists attack by most etching reagents (cold). It may sometimes cause pitting in steel samples, however, and tends to tarnish copper alloys. Bakelite, of which many grades must be molded under pressure, makes a good mount for powdered material, thin sheets and wires or irregular objects in which a longitudinal section is to be examined(**29,2**).[1] Plaster of Paris, DeKhotinsky cement, sealing wax, a litharge glycerine cement, and some special dental cements are also used, especially for non-ferrous metals such as gold, platinum and other precious metals. In choosing the mounting material some consideration must be given to its resistance to attack by the etchants and its effect on the specimen, especially as regards electrolytic attack at the edges.

(*b*) Small wires, odd shapes, fractures, or specimens of which the edges are to be examined, are frequently electroplated before mounting(**3,4,5**) to avoid tearing or rounding off during subsequent polishing. Ferrous materials are usually copper-plated for this purpose. A flash coat in a copper cyanide bath (Note 1) is first applied, followed by plating in a copper sulfate bath (Note 2). The precious metals are frequently plated with nickel, gold or silver, while fractures of many non-ferrous metals are conveniently and successfully silver-plated. The plating metal should be softer than the specimen to avoid differential polishing, which may mask the edge, and should not electrolytically react with the base-metal of the specimen.

Note 1.—For the copper cyanide bath use 22.5 g. of cuprous cyanide, 34 g. of sodium cyanide and 15 g. of sodium carbonate in a liter of water; current density of 0.2 amp. per sq. dm.

Note 2.—For the copper sulfate bath use 250 g. of copper sulfate crystals and 75 g. of concentrated sulfuric acid in a liter of water; current density of 2 to 4 amp. per sq. dm.

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[1] The boldface numbers in parentheses refer to the reports and papers given in the list of references appended to this recommended practice, see p. 1347.

Cleaning Test Specimens

4. Cleanliness during polishing and etching is essential. All grease and oil must first be removed. For galvanized material, the zinc should be removed by dissolving in cold, concentrated HNO_3 or in dilute H_2SO_4, unless, of course, the galvanized coating itself is to be studied. The nitric acid method requires some care to prevent overheating as large samples generate much heat. The container should be immersed in a cooling medium during use. Rusted fractures may be cleaned with a dilute solution of ammonium citrate or phosphoric acid.

IRON AND STEEL

Preparation of Specimens

5. (*a*) Rough grinding on an abrasive wheel or coarse emery paper is usually sufficient, and even machined surfaces may sometimes prove satisfactory for deep etching specimens for macroscopic examination (6). When less severe etching, such as with ammonium persulfate, is to follow, or in sulfur printing, a somewhat smoother finish may be desirable.

(*b*) In polishing for microscopic examination, the specimen should not be too large, preferably not over $\frac{1}{2}$ to 1 in. square and about $\frac{1}{2}$ in. in thickness. A flat surface is obtained either by rubbing the specimen on a file held in a vise or by grinding on an abrasive wheel. The specimen is then ground on emery paper, which may be mounted on disks revolving at about 500 to 1200 r.p.m.; three successive grades of paper, such as Nos. $\frac{1}{2}$, 0, 00, are sufficient. The grinding on each paper should be in one direction, preferably at 90 deg. to that in the preceding stage. This is followed by the wet polishing stages on cloth-covered wheels revolving at about 400 r.p.m. To these are applied water suspensions of No. 320 alundum, No. 600 alundum, and levigated alumina, respectively. The cloth should not be too thick and should have no "nap;" a cotton cloth resembling ordinary linen table cloth in weave and weight works well. The final polishing to remove all scratches is on a velveteen cloth with Merck's heavy magnesia; this should be applied dry by rubbing into the moistened cloth; any rough particles can be felt with the fingers and wiped off to the edge of the disk by hand. During these wet polishing stages the specimen should be intermittently or continuously turned about the vertical axis to avoid pitting. The specimens should be washed after each stage to avoid carrying over any of the abrasives to the next stage and must not be allowed to stand without drying, as deep pits, due to rusting, may form very rapidly. After polishing, the specimen should be washed in warm water (21 C. (70 F.), maximum) or alcohol, swabbed with absorbent cotton moistened in alcohol, and dried in a blast of warmed air (21 C. (70 F.), maximum). Special care should be taken to wash the magnesia wheel in water containing a trace of HCl after using, as the magnesia cakes and hardens by taking up CO_2 from the air.

(*c*) Very satisfactory results can be obtained with the procedure described in Paragraph (*b*), but many other satisfactory variations have been suggested. Vilella(7) omits the intermediate wet polishing stages and goes directly from fine emery paper (No. 000), smoothed by rubbing with graphite, to the final polishing wheel. This reduces the chances of dragging out non-metallic inclusions in steels and graphite in gray and malleable cast iron. A good flat crepe with alumina for the abrasive is said to be a satisfactory substitute for velveteen and magnesia for studying inclusions. It is essential that pitting and dragging out of inclusions(9) and of graphite be avoided; this can be accomplished by the general method outlined in Paragraph (*b*), if care is used. Others(8) also recommend final dry polishing for material containing graphite. Wheels covered with paraffin are used by a number of laboratories, generally with the abrasives suspended in a solution of 50 per cent liquid soap and 50 per cent water. Impregnating the abrasives in the paraffin wheel has been tried(10). Pulsifer(11) omits the final polishing stages and etches after wet polishing on emery flour; alternately etching and polishing.

(*d*) A recommended method for polishing cast iron consists in running through on the four grades of abrasive papers (from Nos. 180 to 400) on vertically mounted wheels rotating at about 500 to 600 r.p.m. The center portion of the No. 400 disk, where the paper has been glazed with graphite, is used for the fifth polishing step. The final polish is made on moistened flat silk crepe which is mounted on a horizontal-type disk rotating at 750 r.p.m. Levigated alumina (which settles at the rate of $\frac{1}{4}$ in. per hr.) is used as the abrasive. This method permits the retention of graphite with a good, scratch-free surface. In general, very soft specimens are more difficult to polish than hard ones. Specimens about $\frac{1}{4}$ in. or $\frac{3}{8}$ in. square are preferred to larger sizes, due to the shorter time required for any given step in the polishing procedure, particularly on the silk crepe wheel. The less time spent in the last stages of polishing, the better are the chances for complete retention of graphite. Sulfur has been found to be a satisfactory mounting material.

(*e*) Polishing machines in which the specimen is held and rotated automatically have been employed(1,12) and are being more and more extensively used.

(*f*) Various abrasives have been used (1,8,13). Rodda(14) has described a method for preparing graded abrasives for metallographic polishing but for most work, however, the commercially obtainable abrasives and polishing powders are satisfactory. Ordinary levigated alumina purchased in bulk may be re-levigated just before using by suspending in water for about a minute or longer and siphoning. Silicon carbide and boron carbide powders and diamond dust have been recommended by Hoyt(15) for polishing tungsten carbide.

Etching

6. In general, polished metal shows no trace of crystalline structure; etching is used to clearly delineate the structure and to produce optical contrast between the various constituents. A great number of etching reagents and methods for iron and steel have been proposed, but the majority of work can be done with relatively few reagents.

TABLE I.—ETCHING REAGENTS FOR MACROSCOPIC EXAMINATION OF IRON AND STEEL.

Etching Reagent	Composition		Remarks	Use
No. 1. Hydrochloric acid	HCl (conc.) H_2O	50 ml. 50 ml.	Used hot or boiling for about 10 to 15 min. depending on the steel.	Showing segregation, porosity, cracks, depth of hardened zone in tool steel, soft spots, etc.
No. 2. Mixed acid	HCl (conc.) H_2SO_4 (conc.) H_2O	38 ml. 12 ml. 50 ml.	Recommended by Yatsevitch (19); to be used as above for from 15 to 45 min.	Same as for reagent No. 1; works well for stainless steel.
No. 3. Nitric acid	HNO_3 (conc.) H_2O	25 ml. 75 ml.	Used cold for large surfaces such as split ingots which cannot conveniently be heated.	Same as for reagents Nos. and 2.
No. 4. Ammonium persulfate	$(NH_4)_2S_2O_8$ H_2O	10 g. 90 ml.	Surface should be rubbed with absorbent cotton during etching.	To bring out grain structure in cases of excessive grain growth, recrystallization at welds, etc.
No. 5. Stead's reagent	Cupric chloride Magnesium chloride HCl (conc.) Alcohol	2.5 g. 10.0 g. 5 ml. Up to 250 ml.	The salts are dissolved in the HCl with the addition of the least possible quantity of hot water.	To bring out phosphorus-rich areas and phosphorus banding.
No. 6. Fry's reagent	Cupric chloride HCl (conc.) H_2O	90 g. 120 ml. 100 ml.	Most useful for mild steel, particularly bessemer steel; before etching, sample should be heated to 200 to 250 C. (302 to 482 F.) for 5 to 30 min., depending on the condition of the steel; during etching the surface should be rubbed with a cloth soaked in the etching solution; wash in alcohol or rinse in HCl (1:1) after etching to prevent deposition of copper.	To show up strain lines due to cold work.
No. 6A. Fry's reagent	Cupric chloride HCl (conc.) H_2O	45 g. 180 ml. 100 ml.	Same as for reagent No. 6 but modified by Wazau; may give more contrast; specimen can be washed in water without depositing copper.	Same as for reagent No. 6.
No. 7. Nital	HNO_3 Ethyl alcohol	5 ml. 95 ml.	Etch 5 min., followed by 1 sec. in HCl (10 per cent).	To determine cleanness and to increase contrast.

Etching for Macroscopic Examination

7. (*a*) In deep etching (16,17,18,19), hot solutions of HCl or H_2SO_4, or mixtures of these acids, are generally used; deep etching reveals physical and chemical non-homogeneity such as porosity, cracks, seams and segregation; an aqueous solution of ammonium persulfate brings out the grain structure; Stead's reagent, phosphorus banding; Fry's reagent, strain

lines. Cooling low-carbon steel specimens in either ordinary or "dry" ice prior to etching is said to improve grain boundary contrast. For photographing, increased contrast is obtained by washing after etching and applying glycerin to the etched surface.

(*b*) In Table I are given the etching reagents commonly recommended for macroscopic examination of iron and steel. A more complete discussion is given by Berglund(20).

Sulfur Printing

8. This is a macroscopic method for revealing sulfur segregation and the size and distribution of the sulfides.

(*a*) The surface of the specimen is pressed against a sheet of photographic paper which has been moistened with a dilute aqueous solution of sulfuric acid (2 to 10 per cent). Matte-finish photographic paper is preferable to prevent slipping. A few seconds to about a minute contact may be necessary depending on the sulfur content. Yellow or brown specks on the paper indicate the presence of sulfides in the specimen. The prints are fixed in sodium thiosulfate ("hypo"), washed, and dried. Transparent silver bromide paper can also be used(21) to give a sulfur print transparency from which contact prints in any number can be made on ordinary photographic paper. Berglund(20) has given a detailed discussion of sulfur printing.

(*b*) There is some question whether the presence of phosphorus will also give a yellow color. Royen and Ammermann(22) state that prints made on gelatin paper with use of the following solutions reveal only sulfur; phosphorus having no effect:

Solution No. 1....	25 g. of cadmium acetate plus 200 ml. of acetic acid (80 per cent) to which is added a solution of 500 ml. of H_2SO_4 in 950 ml. of H_2O.
Solution No. 2....	120 g. of $CuSO_4$ plus 880 ml. of H_2O plus 120 ml. of H_2SO_4.

The specimen to be tested is pressed for 2 to 4 min. upon gelatin paper which has been treated with solution No. 1, and yellow cadmium acetate is precipitated. By immersion for 2 to 3 min. in solution No. 2, this is transformed to the dark brown to black Cu_2S.

Etching for Microscopic Examination

9. (*a*) Mild etching solutions are generally used for microscopic examination. For carbon steels, solutions of picric or nitric acid in ethyl alcohol are most commonly employed; alkaline solutions like sodium picrate or potassium ferricyanide are used for darkening the carbides; for stainless steel aqua regia diluted in glycerin gives good results while electrolytic etching is frequently employed.

(*b*) The polished and thoroughly cleaned sample is immersed in the solution face up by means of nickel or other corrosion-resisting etching

TABLE II.—ETCHING REAGENTS FOR MICROSCOPIC EXAMINATION OF IRON AND STEEL.

Etching Reagent	Composition		Remarks	Uses
No. 1. Nitric acid (2 per cent Nital)	HNO_3 (conc.) Ethyl alcohol (abs.)	2 ml. 98 ml.	Only clear white HNO_3 (sp. gr. 1.42) should be used; time, a few seconds to about a minute.	For carbon steel, iron, and cast iron. Nital brings out grain boundaries clearly; carbides are unetched; for the structures of nitrided steels.
No. 1A. Nitric acid (1 per cent Nital)	HNO_3 (conc.) Ethyl alcohol	1 ml. 99 ml.	See reagent No. 1.	For tempered samples.
No. 2. Picric acid (5 per cent Picral)	Picric acid Ethyl alcohol (abs.)	5 g. 100 ml.	Clean, dry, picric acid crystals should be used; time, a few seconds to about a minute or more.	Same as reagent 1A; the grain size of quenched steels is brought out after prolonged etching; picral shows detail more delicately than nital.
No. 3. Sodium picrate	Picric acid Sodium hydroxide H_2O	2 g. 25 g. 100 ml.	Use boiling, 5 to 10 min.	Colors cementite, but not carbides high in chromium; in tungsten steels, iron-tungstide (Fe_nW) and iron-tungsten-carbide (Fe_2W_2C) are colored, but tungsten carbide is unaffected; attacks sulfides.
No. 4 Ferricyanide solution	Potassium ferricyanide Potassium hydroxide H_2O	10 g. 10 g. 100 ml.	May be used cold, but preferably hot; should be freshly made; time, 5 to 10 min.	Darkens carbide containing chromium; carbides and tungstides in tungsten and high-speed steels. At room temperature colors ternary carbides (Fe_2W_3C or Fe_4W_2C) in a few seconds, iron tungstide (Fe_3W_2) in several minutes, and barely colors cementite.
No. 5. Hydrogen peroxide and sodium hydroxide	H_2O_2 10 per cent NaOH, aqueous solution	10 ml. 20 ml.	Use fresh; etch 10 to 12 min.	Darkens iron tungstide in carbon-free iron-tungsten alloys. When carbon is present this solution darkens the compound (FeW+WC?) in proportion to the amount of carbon present; tungsten carbide is darkened.
No. 6 Stead's reagent	Cupric chloride Magnesium chloride HCl (conc.) H_2O Ethyl alcohol	1 g. 1 g. 1 ml. 20 ml. 100 ml.	Dissolve the salts in the least possible quantity of hot water; etch for about a minute; should be used with discrimination.	For showing segregation of phosphorus; copper tends to deposit first on areas poorer in phosphorus.
No. 7. Fry's microreagent	HCl (conc.) H_2O Cupric chloride Ethyl alcohol	40 ml. 30 ml. 5 g. 25 ml.	Time, about 10 sec.	To reveal strain lines and precipitation effects in "aged" steel. Requires careful examination.
No. 8. Mixed acids in glycerol	Glycerin HNO_3 (conc.) HCl (conc.) Acetic acid (28 per cent)	3 parts 1 part 2 parts 1 part	Time, about 30 sec. or longer; method of alternate polishing and etching should be used.	For 18 per cent chromium, 8 per cent nickel stainless steel; also for structure of iron-chromium base alloys containing aluminum, tungsten, vanadium, manganese, nickel and molybdenum(**93**).
No. 9. Chrome-regia	HCl (conc.) Chromic acid (10 per cent)	25 parts 5 to 50 parts	The activity of this solution is controlled by the amount of chromic acid.	For 18 per cent chromium, 8 per cent nickel stainless steel(**93**).
No. 10. Ferric chloride	Ferric chloride HCl (conc.) H_2O	5 g. 50 ml. 100 ml.	Time, about a minute.	For austenitic nickel-steels(**93**).

Table II (*Continued*).

Etching Reagent	Composition		Remarks	Uses
No. 11. Marble's reagent	Copper sulfate HCl (conc.) H_2O	4 g. 20 ml. 20 ml.	May also be used hot; time about a minute.	For structure of stainless steel, particularly to reveal extent of carbide precipitation in 18 per cent chromium, 8 per cent nickel steel; total depth of nitrided case(**93**).
No. 12. Copper sulfate and cupric chloride	H_2O $CuSO_4$ $CuCl_2$ MgCl HCl (conc.) Dilute to 1000 ml. with 95 per cent ethyl alcohol.	100 ml. 1.25 g. 2.5 g. 10 g. 2 ml.	Chemicals should be accurately weighed. Time, about 30 sec. or less to a minute.	For showing total depth, structure, and various zones of nitrided steels.
No. 13. Ferricyanide solution	Potassium ferricyanide Potassium hydroxide H_2O	1 to 4 g. 10 g. 10 ml.	Use a freshly made boiling solution for 15 min.	Shows difference between carbides and nitrides; cementite is blackened, pearlite is turned brown, and massive nitrides remain unchanged.
No. 14. Neutral sodium picrate	1 per cent neutral sodium picrate solution.		Wash salt well with alcohol to remove excess picric acid or alkali, immerse in boiling solution for 20 min.	Darkens iron tungstide in high speed steel but not the complex carbide; darkens iron-phosphide in cast iron but not cementite.
No. 15. Chromic acid and heat tinting	8 per cent chromic acid, followed by heat tinting.		Etch first in picric acid, then for 1 min. in chromic acid; heat tint by placing specimen face up on a hot plate heated to about 250 C. (500 F.) for about a minute.	Distinguishes between iron-phosphide and cementite in the phosphide eutectic of cast iron; iron-phosphide is colored darker.
No. 16. Hydrofluoric acid	HF HNO_3 Glycerol	2 parts 1 part 2 to 4 parts	Time, about 1 min.	For structure of high silicon alloys of the duriron type.
No. 17. Iodine solution	0.1 *N* iodine solution Alcohol	1 part 10 parts	Time, 5 to 15 min.	For detecting silicon dissolved in iron; higher silicon areas more lightly etched.
No. 18. Electrolytic etching	Copper ammonium chloride H_2O Current density 0.5 amp. per sq. dm.	0.5 g. 100 ml.	Time, 30 min., repeated etching and polishing.	To develop etching pits in iron.
No. 19. Mixed acids.	HCl HNO_3	3 parts 1 part	Saturate with cupric chloride and let stand 20 to 30 min. before use. Swab.	For stainless alloys and others high in nickel or cobalt.
No. 20. Nitric and acetic acid	HNO_3 Acetic acid	6 parts 4 parts	Swab.	Same as for reagent No. 19.
No. 21. Nitric acid in nitrobenzol(**94**).	HNO_3 (conc.) Methyl alcohol Add 40 drops of above solution to 50 ml. nitrobenzol.	20 ml. 80 ml.	Immerse specimen about 5 to 15 sec., rinse in alcohol, swab with concentrated NaOH to remove film, rinse in alcohol. Use only anhydrous acid and alcohol in reagent.	For detecting cementite, particularly in silicon steels. Used instead of reagent No. 3.

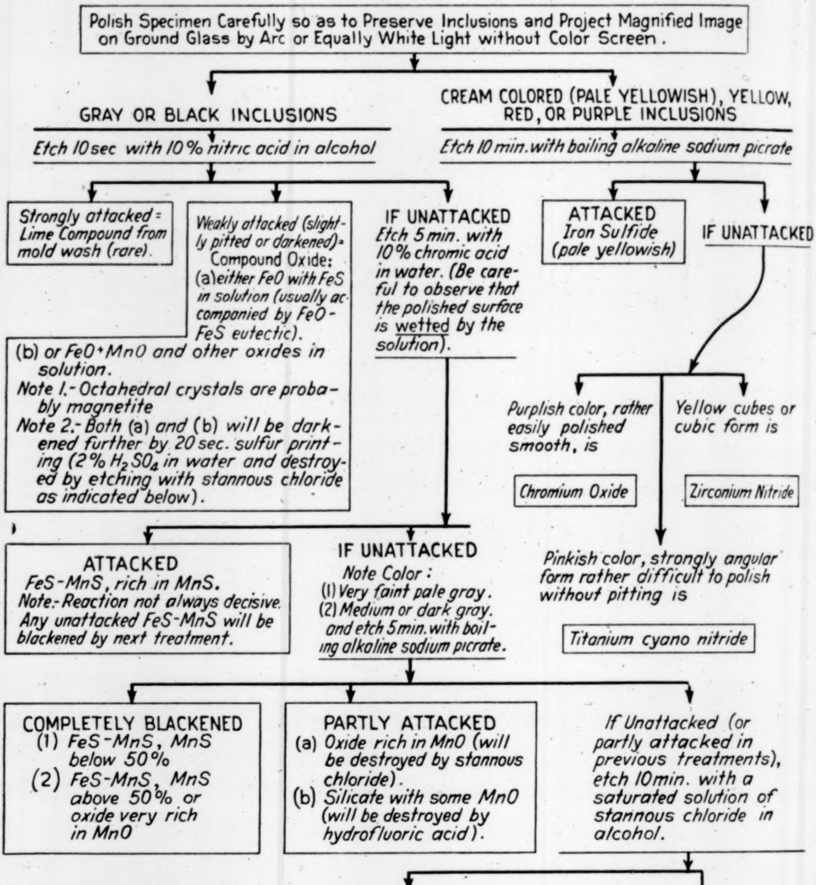
Polish Specimen Carefully so as to Preserve Inclusions and Project Magnified Image on Ground Glass by Arc or Equally White Light without Color Screen.
GRAY OR BLACK INCLUSIONS
Etch 10 sec with 10% nitric acid in alcohol
CREAM COLORED (PALE YELLOWISH), YELLOW, RED, OR PURPLE INCLUSIONS
Etch 10 min. with boiling alkaline sodium picrate
Strongly attacked = Lime Compound from mold wash (rare).
Weakly attacked (slightly pitted or darkened) = Compound Oxide: (a) either FeO with FeS in solution (usually accompanied by FeO-FeS eutectic). (b) or FeO+MnO and other oxides in solution.
Note 1.- Octahedral crystals are probably magnetite
Note 2.- Both (a) and (b) will be darkened further by 20 sec. sulfur printing (2% H₂SO₄ in water and destroyed by etching with stannous chloride as indicated below).
IF UNATTACKED Etch 5 min. with 10% chromic acid in water. (Be careful to observe that the polished surface is wetted by the solution).
ATTACKED Iron Sulfide (pale yellowish)
IF UNATTACKED
Purplish color, rather easily polished smooth, is
Chromium Oxide
Yellow cubes or cubic form is
Zirconium Nitride
Pinkish color, strongly angular form rather difficult to polish without pitting is
Titanium cyano nitride
ATTACKED FeS-MnS, rich in MnS. Note:- Reaction not always decisive. Any unattacked FeS-MnS will be blackened by next treatment.
IF UNATTACKED Note Color: (1) Very faint pale gray. (2) Medium or dark gray. and etch 5 min. with boiling alkaline sodium picrate.
COMPLETELY BLACKENED (1) FeS-MnS, MnS below 50% (2) FeS-MnS, MnS above 50% or oxide very rich in MnO
PARTLY ATTACKED (a) Oxide rich in MnO (will be destroyed by stannous chloride). (b) Silicate with some MnO (will be destroyed by hydrofluoric acid).
If Unattacked (or partly attacked in previous treatments), etch 10 min. with a saturated solution of stannous chloride in alcohol.
ATTACKED Iron Oxide or (if previously pitted) compound oxide.
If Unattacked (or previously pitted) etch 10 min. with 20% aqueous solution of hydrofluoric acid.
ATTACKED Silicate (if previously pitted presence of Mn is indicated).
IF UNATTACKED Repolish and note color and form.
If fine particles very dark color, difficult to polish without pitting and not elongated by hot work is
Alumina
If color not especially dark, easily polished smooth without pitting
Fairly large angular fragments showing changeable bright spots as focus is changed are
Sand Grains (in steel castings)
Small angular particles bluish in color
Probably Titanium oxide (in titanium treated steel)
SUPPLEMENTARY TESTS
In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:
I Sulfur Printing (for 20 sec. using a 2% aqueous solution of H₂SO₄):
(1) Dissolves all FeS-MnS inclusions.
(2) Partly dissolves (pits) FeO containing FeS and oxides of other metals in solution.
(3) Leaves unchanged; iron sulfide (pale yellow) pure iron oxide (medium gray) silicates (dark gray).
II Matweieff's Tests. See Sauveur's "Metallography and Heat Treatment of Iron and Steel", pp. 512 and 513 (1926).
III Rohl's Tempering Test for Sulfides. Same reference as in II. p. 513.

FIG. 2.—Method for Identification of Inclusions in Iron and Steel. (By Campbell and Comstock, Modified by **Wöhrman**.)

tongs. During etching it is often desirable to stir the solution gently or to swab the surface with absorbent cotton to avoid deposition of smudge; for stainless steel this is necessary to also prevent gas bubbles from clinging to the surface. The progress of etching can generally be observed visually, but it should also be carefully timed. If the sample is not etched sufficiently, the process may be repeated, but if it is overetched the sample may have to be repolished or even reground; too deep etching, therefore, should be avoided. It may frequently be necessary, especially with stainless steel, to etch, repolish, and re-etch, in order to remove the surface layer of deformed metal produced during grinding and polishing.

(*c*) In Table II are given the etching reagents commonly recommended for microscopic examination of iron and steel. More extended discussions are given by Berglund(20) and in the National Metals Handbook(23).

Identification of Inclusions in Iron and Steel

10. The method for identifying inclusions in iron and steel, worked out by Campbell and Comstock and modified by Wöhrman, is given in Fig. 2. A microscopic method for determining the amount of inclusions or the cleanness of a heat of steel has been described by Epstein(24).

Detection of Cracks and Pin Holes

11. (*a*) Cracks are readily revealed by deep etching (a 15 per cent solution of sulfuric acid in water works well for grinding cracks), but this method may be too destructive for some purposes and may actually cause cracks. For fine cracks such as may be produced by quenching, fatigue, or in grinding hardened steel, the following magnetic method is useful: The roughly polished specimen is magnetized by suitable means and fine iron powder dusted on the surface. The iron particles bridge across discontinuities in the specimen and thus locate the cracks. Under certain conditions it is preferable to immerse the magnetized specimen in a light oil in which the iron powder is held in suspension. Suitable iron powder (''magnaflux'') can be purchased(25). Bitter(26) has used a similar method to reveal inhomogeneities in the crystal structure. Another method is to place the part to be tested in warm oil, clean thoroughly, and paint with lime; the presence of cracks is revealed by oil spots in the lime. In still another method the sample is immersed in a sulfide solution; due to the capillary effect some of the solution is sucked into any crevices present. The sample is then cleaned and pressed against photographic paper moistened in dilute sulfuric acid; black silver sulfide is formed at the cracks.

(*b*) A reliable method(27) for determining the porosity of tin coatings and other cathodic coatings on iron and steel is to place the coated sheet in not distilled water for several hours. Very adherent and visible rust spots form at the pores. The ferricyanide test(28) is more rapid. Suitable paper can be purchased or may be prepared by immersing white typewriter or blotting paper in the following solution for 30 min.: 60 g. of sodium chloride, 10 g. of potassium ferricyanide, and 1000 ml. of water. The sample after degreasing is dampened with water, and a sheet of the prepared paper is placed on the surface and gently smoothed out; after a few minutes contact, the paper is removed, washed, and dried. Blue spots indicate the presence of pin holes. This test is not suitable for testing the porosity of tin plate which has been subjected to cold work such as bending or stretching.

ALUMINUM AND ITS ALLOYS

Preparation of Specimens

12. The methods described in the following Paragraphs (*a*) to (*d*) for preparing specimens of aluminum and its alloys for microscopic examination have been recommended(29,30):

(*a*) A plane surface is obtained and saw-marks removed by rubbing on a medium mill file. After the file cut, the specimen is rubbed successively on Nos. 0, 00, and 000 metallographic emery papers coated with a solution of paraffin in kerosine to keep the specimen bright and prevent embedding particles of the abrasive in the surface.

(*b*) If a suitable microtome is available(31), a more satisfactory surface can be obtained by using it to replace the two operations described in Paragraph (*a*).

(*c*) The first wet polishing operation is carried out on a broadcloth-covered wheel rotating at about 300 r.p.m. A water suspension of No. 600 alundum flour (or a similar material) is generally used as the abrasive. This mixture is conveniently prepared by placing a quantity of the abrasive in a flask of water and shaking until it is in suspension. It can then be supplied to the wheel directly from the flask while the specimen is held in contact with the broadcloth. The alundum tends to settle, so the flask should be shaken frequently during the early stages of polishing. As polishing progresses, however, the coarser abrasive should be washed from the wheel with a stream of water from a wash bottle and a suspension used, from which the coarser particles have been settled out.

(*d*) The final wet polishing operation is carried out on a wheel covered with "kitten's ear" broadcloth and rotating at about 150 to 200 r.p.m. The cloth (Note 1) is thoroughly moistened with distilled water (*not* tap water) and Merck's heavy magnesium oxide powder (Note 2) worked into it with the fingers or palm of the hand, brushing away any coarse particles. The cloth should be kept moist with distilled water at all times during polishing and, near the end of the operation, should be washed nearly free of abrasive; finishing the polishing with the wheel rotating slowly and using a plentiful supply of water. This final polishing must be done very carefully, varying the pressure and time of polishing with the alloy and temper of the specimen. The polishing on this second wheel should remove all striations from the alundum cut and the specimen should frequently be turned through 180 deg. to avoid surface flow.

NOTE 1.—New polishing cloths should be boiled in distilled water for several hours prior to use in order to soften the fibers. When not in use, the cloth should be kept in distilled water slightly acidified with hydrochloric acid.

NOTE 2.—Several grades of magnesium oxide are prepared specifically for metallographic use and have been found satisfactory for polishing other metals. When used for aluminum, however, the caustics they contain result in undesirable etching.

TABLE III.—ETCHING REAGENTS FOR ALUMINUM AND ITS ALLOYS.

Etching Reagent[a]	Composition		Remarks	Use
No. 1. Hydrofluoric acid (33 to 42)	HF (conc.) H_2O	0.5 ml. 99.5 ml.	Swab with soft cotton for 15 sec.	General; microscopic.
No. 2. Sodium hydroxide (33 to 42)	NaOH H_2O	1 g. 99 ml.	Swab for 10 sec.	General; microscopic.
	or NaOH H_2O	 10 g. 90 ml.	Immerse for 5 sec. at 70 C. (160 F.); rinse in cold water.	Can be used for both micro and macroetching.
No. 3. Sulfuric acid (43)	H_2SO_4 (conc.) H_2O	20 ml. 80 ml.	Immerse for 30 sec. at 70 C. (160 F.); quench in cold water.	Aluminum-copper-iron-manganese from aluminum-iron-manganese or aluminum-copper-iron.
No. 3A. Sulfuric acid (44)	H_2SO_4 (conc.) H_2O	10 ml. 90 ml.	Immerse at 60 to 70 C.	$FeAl_3$.
No. 4. Nitric acid (45)	HNO_3 (conc.) H_2O	25 ml. 75 ml.	Immerse for 40 sec. at 70 C. (160 F.); quench in cold water.	α Aluminum-iron-silicon from $FeAl_3$; microscopic.
No. 5. Keller's etch (46)	HF (conc.) HCl (conc.) HNO_3 (conc.) H_2O	1.0 ml. 1.5 ml. 2.5 ml. 95.0 ml.	Immerse for 10 to 20 sec.; wash in stream of warm water.	Microstructure of duralumin type alloys.
No. 6. Flick's etch (47)	HF (conc.) HCl (conc.) H_2O	10 ml. 15 ml. 90 ml.	Immerse for 10 to 20 sec.; wash in warm water followed by dip in concentrated HNO_3.	Macroscopic etching.
No. 7. Tucker's etch (48)	HF (conc.) HCl (conc.) HNO_3 (conc.) H_2O	15 ml. 45 ml. 15 ml. 25 ml.	Etch by immersion.	Macroscopic.
No. 8. Vilella's etch (49)	HF (conc.) HNO_3 (conc.) Glycerine	2 parts 1 part 3 parts		General.

[a] A number of other etching solutions or variations of those given above have been suggested by Czochralski (50), Merica (37,38), Hanson (36), Anderson (40), Meyer (44) and Blumenthal (52).

(*e*) When polishing is complete, the specimen should be washed in a stream of warm water and dried by blowing the excess water from the surface. The polished surface must not be touched or rubbed on anything thereafter. Specimens will retain their finish indefinitely if kept in a desiccator or sterilizer cabinet where dust, dirt and moist gases from the atmosphere will not collect on the surface.

(*f*) Specimens to be examined macroscopically need not be polished as carefully as those for microscopic examination. If large enough, they may be suitably prepared by machining the surface on a shaper or lathe using the recommended practice for machining aluminum(32). Small specimens may be prepared by rubbing on several grades of abrasive paper beginning with about No. 180 aloxite and ending with No. 0 emery.

Etching Reagents

13. (*a*) In Table III are given the etching reagents commonly recommended for aluminum and its alloys.

(*b*) Two methods of etching are referred to in Table III; swabbing and immersion. Swabbing gives generally uniform and satisfactory results and is especially desirable for preparing surfaces for photography or identification of constituents. For macroscopic examination, however, etching by immersion is preferred unless the specimen is too large. When the immersion method is used, the specimen should not be held in the tongs during etching as they are of a different alloy and may affect the etching rate.

(*c*) It is very important to control the temperature of the specimen and the reagent, the time of etching and the concentration of the reagent in order to secure the best results.

Examination and Identification of Constituents

14. (*a*) The first attempt to identify constituents is made on the unetched specimen, using color and manner of occurrence as a means of differentiation. Examination at a magnification of 500 diameters using a 4-mm. objective and a 10× ocular is recommended.

(*b*) For judging the color it is advisable to employ light approximating daylight. Addition of an Eastman No. 78A filter (which has a bluish tint) converts the light of a 5-amp. carbon arc with Eastman neutral tint filter to that of approximately daylight. Any white light will give about the same results, although the bluish tints aid in the separation of the different constituents.

(*c*) The schematic diagram shown in Fig. 3 has been proposed(30) as a guide in the identification of constituents. It is, of course, subject to the limitations of any etching procedure, but should prove adequate in the majority of cases to determine the alloy type or general composition. Some experience is necessary for the satisfactory identification of constituents. Such experience is usually gained by a study of standard samples containing known constituents. A very interesting series of photomicrographs was published(30) in connection with the diagram given in Fig. 3.

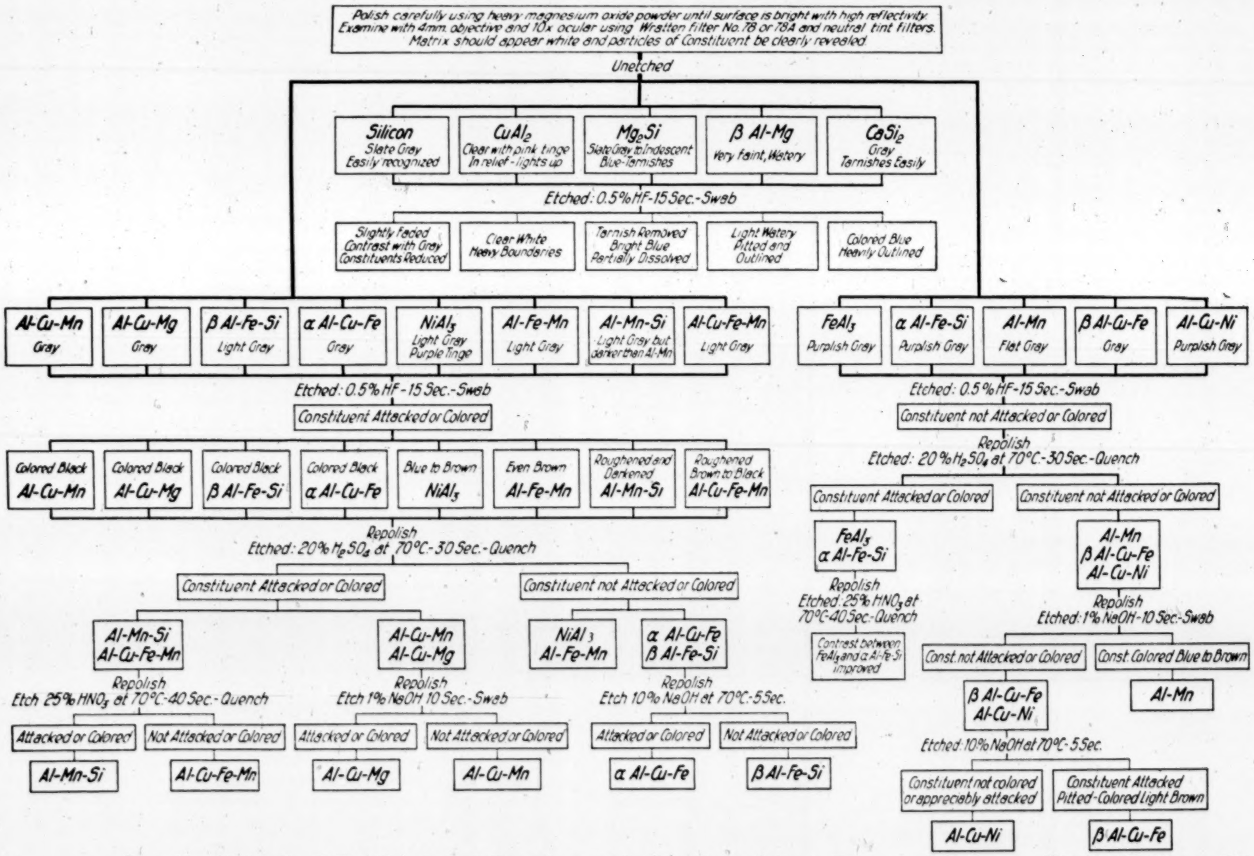
Polish carefully using heavy magnesium oxide powder until surface is bright with high reflectivity. Examine with 4mm. objective and 10x ocular using Wratten filter No. 78 or 78A and neutral tint filters. Matrix should appear white and particles of Constituent be clearly revealed.
Unetched
Silicon Slate Gray Easily recognized
CuAl2 Clear with pink tinge In relief - lights up
Mg2Si Slate Gray to Iridescent Blue-Tarnishes
β Al-Mg Very faint, Watery
CaSi2 Gray Tarnishes Easily
Etched: 0.5% HF-15 Sec.-Swab
Slightly Faded Contrast with Gray Constituents Reduced
Clear White Heavy Boundaries
Tarnish Removed Bright Blue Partially Dissolved
Light Watery Pitted and Outlined
Colored Blue Heavily Outlined
Al-Cu-Mn Gray
Al-Cu-Mg Gray
β Al-Fe-Si Light Gray
α Al-Cu-Fe Gray
NiAl3 Light Gray Purple Tinge
Al-Fe-Mn Light Gray
Al-Mn-Si Light Gray but darker than Al-Mn
Al-Cu-Fe-Mn Light Gray
FeAl3 Purplish Gray
α Al-Fe-Si Purplish Gray
Al-Mn Flat Gray
β Al-Cu-Fe Gray
Al-Cu-Ni Purplish Gray
Etched: 0.5% HF-15 Sec.-Swab
Constituent Attacked or Colored
Colored Black Al-Cu-Mn
Colored Black Al-Cu-Mg
Colored Black β Al-Fe-Si
Colored Black α Al-Cu-Fe
Blue to Brown NiAl3
Even Brown Al-Fe-Mn
Roughened and Darkened Al-Mn-Si
Roughened Brown to Black Al-Cu-Fe-Mn
Repolish
Etched: 20% H2SO4 at 70°C.-30 Sec.-Quench
Constituent Attacked or Colored
Constituent not Attacked or Colored
Al-Mn-Si Al-Cu-Fe-Mn
Al-Cu-Mn Al-Cu-Mg
NiAl3 Al-Fe-Mn
α Al-Cu-Fe β Al-Fe-Si
Repolish
Etch 25% HNO3 at 70°C.-40 Sec.-Quench
Repolish
Etch 1% NaOH 10 Sec.-Swab
Repolish
Etch 10% NaOH at 70°C.-5 Sec.
Attacked or Colored
Not Attacked or Colored
Attacked or Colored
Not Attacked or Colored
Attacked or Colored
Not Attacked or Colored
Al-Mn-Si
Al-Cu-Fe-Mn
Al-Cu-Mg
Al-Cu-Mn
α Al-Cu-Fe
β Al-Fe-Si
Etched: 0.5% HF-15 Sec.-Swab
Constituent not Attacked or Colored
Repolish
Etched: 20% H2SO4 at 70°C.-30 Sec.-Quench
Constituent Attacked or Colored
Constituent not Attacked or Colored
FeAl3 α Al-Fe-Si
Repolish
Etched: 25% HNO3 at 70°C-40 Sec.-Quench
Contrast between FeAl3 and α Al-Fe-Si improved
Al-Mn β Al-Cu-Fe Al-Cu-Ni
Repolish
Etched: 1% NaOH-10 Sec.-Swab
Const. not Attacked or Colored
Const. Colored Blue to Brown
β Al-Cu-Fe Al-Cu-Ni
Al-Mn
Etched: 10% NaOH at 70°C.-5 Sec.
Constituent not colored or appreciably attacked
Constituent Attacked Pitted-Colored Light Brown
Al-Cu-Ni
β Al-Cu-Fe

FIG. 3.—Guide for Identification of Constituents in Aluminum Alloys (Keller and Wilcox). (Courtesy: *Metal Progress* (30))

COPPER AND ITS ALLOYS(52,59)

Preparation of Specimens

15. (*a*) In the preparation of copper and copper alloy specimens for microscopic examination, a plane surface is secured by filing or with an emery wheel copiously supplied with water. The specimen is then polished, generally in three stages, on wheels rotating at 1000 to 1800 r.p.m.

TABLE IV.—ETCHING REAGENTS FOR COPPER AND ITS ALLOYS.

Etching Reagent	Composition		Remarks	Use
No. 1. Ammonium hydroxide - hydrogen peroxide	NH_4OH (sp. gr. 0.88) H_2O H_2O_2 (3 per cent)	5 parts 5 parts 2 to 5 parts	Peroxide content varies directly with copper content of alloy to be etched. Immersion or swabbing for about 1 min. Fresh H_2O_2 is desirable for good results.	Generally used for copper and many of its alloys. Film on etched aluminum bronze removed by weak Grard's solution.
No. 2. Ammonium hydroxide(60,61)	Dilute solutions.		Immersion.	Polish-attack etching of brass and bronze.
No. 3. Ammonium hydroxide - ammonium persulfate(61)	NH_4OH H_2O $(NH_4)_2S_2O_8$ (2.5 per cent solution)	1 part 1 part 2 parts	Immersion.	Polish-attack of copper and some alloys.
No. 4. Ammonium persulfate	$(NH_4)_2S_2O_8$ H_2O	10 g. 90 ml.	Use either cold or boiling. Immersion.	Copper, brass, bronze, nickel silver, aluminum bronze.
No. 5. Chromic acid	Saturated aqueous solution (CrO_3).		Immersion or swabbing.	Copper, brass, bronze, nickel silver (plain etch).
No. 6. Chromic acid - hydrochloric acid(53)	CrO_3 (10 to 15 per cent) HCl	50 ml. 1 to 2 drops.	Add HCl at time of use. Immersion.	Same as reagent No. 5. Color by electrolytic etching or $FeCl_3$ reagents.
No. 7. Chromic acid - nitric acid(55)	HNO_3 (conc.) H_2CrO_4 H_2O or HNO_3 H_2CrO_4 H_2O	50 ml. 20 g. 30 ml. 5 ml. 20 g. 75 ml.	Immersion.	Aluminum bronze; film from polishing removed by 10 per cent HF.
No. 8. Copper ammonium chloride - ammonium hydroxide(52)	10 per cent aqueous solution of copper ammonium chloride plus NH_4OH to neutral or alkalinity.		Immersion. Wash specimen thoroughly.	Best for darkening large areas of beta in alpha-beta brass. Copper, brass, nickel silver.
No. 9. Ferric chloride (52,54,62)	PARTS $FeCl_3$ HCl H_2O		Immersion or swabbing. Etch lightly or by successive light etches to required results.	Copper, brass, bronze, aluminum bronze; darkens beta in brass; gives contrast following bichromate and other etches.
	5 50 100			
	19 6 100		Grard's No. 1.	
	5 10 100		Grard's No. 2.	
	25 25 100			
	1 20 100			
	8 25 100			
	10 1 100		Plus 1 part CrO_3.	
	3 10 100		Plus 1 part $CuCl_2$ and 0.05 part $SnCl_2$.	
No. 10. Nitric acid(60)	Various concentrations.		Immersion or swabbing.	Deep etching.
No. 11. Potassium bichromate(52,53)	$K_2Cr_2O_7$ H_2SO_4 (sp. gr. 1.84) NaCl (saturated solution) H_2O	2 g. 8 ml. 4 ml. 100 ml.	NaCl can be replaced by 1 drop HCl to 25 ml. solution added just before using. Immersion.	Copper, copper alloys of beryllium, manganese, silicon, nickel silver and bronze. Followed by $FeCl_3$ or other contrast etch.
No. 12. Electrolytic etch (52,56,60,61)	$FeSO_4$ NaOH H_2SO_4 H_2O	30 g. 4 g. 100 ml. 1900 ml.	Use 0.1 amp. at 8 to 10 v. Generally not over 15 sec. Do not swab surface after etching.	Darkens beta in brass, gives contrast after H_2O_2 etch. Nickel silver, bronze and other alloys.

(*b*) The first wheel is covered with 8 to 12-oz. canvas duck and uses FF Turkish emery, No. 500 carborundum, or powdered alundum as an abrasive. The second wheel is covered with wool broadcloth and uses tripoli as the abrasive (two felt-covered wheels may be used instead; the first with "RF" and the second with "SF 6X" flour emery as abrasives). The final wheel has a covering of either fine grade wool or "kitten's ear" broadcloth and employs a water suspension of levigated alumina or finely powdered magnesium oxide as an abrasive (chamois has been used as a covering for this wheel and jeweler's rouge as an abrasive).

(*c*) All polishing wheels are kept wet during use by a water drip and the specimens, between steps, are kept wet and thoroughly rinsed free of abrasives. After removal from the final wheel, the specimen may be immediately etched or rinsed in alcohol and quickly dried prior to etching. In much of the routine preparation of specimens, the final etching is depended upon to remove many shallow scratches. When rouge is being used on the final wheel, it is possible to remove the specimen at a critical moment when the polished face becomes clean and dry, and etch directly.

(*d*) Pure copper is more difficult to polish than its alloys, since a nearly perfect surface is required in order to detect the presence of cuprous oxide in the unetched specimen.

(*e*) For macroscopic examination, the specimen may be prepared by grinding and rough polishing or by finishing with a fine tool on a shaper.

Etching Reagents

16. In Table IV are given the etching reagents commonly recommended for copper and its alloys.

Examination and Identification of Constituents

17. Combinations of etches are frequently employed in the examination of copper alloys in order to secure contrast between several constituents. For instance, when alpha and beta structures are both present, a ferric chloride etch following the ammonium hydroxide - hydrogen peroxide etch will darken the beta constituent. Similarly, a beautiful coloration of copper and phosphor-bronze can be obtained by following an ammonium hydroxide - hydrogen peroxide etch with a few seconds of electrolytic etching. In etching the copper-beryllium alloys, the specimen is frequently given a slight initial etch in potassium bichromate, followed by 10 to 15 sec. in the electrolytic solution.

LEAD AND ITS ALLOYS

Preparation of Specimens

18. (*a*) The preparation of lead and lead alloy specimens is difficult because their softness results in surface flow and cold working which masks

the true structure. Although it is generally agreed that a surface free of cold work is almost impossible to obtain by polishing, this is now neither necessary nor particularly advantageous for common leads and alloys with but small amounts of other elements in solution, since recent developments in etching make the uniform removal of cold worked material possible. Alloys containing hard constituents, however, present more difficulty because of uneven attack by etching solutions.

(*b*) A number of methods for preparing specimens are in regular use; the choice for a given specimen generally depending upon the alloy, the size and shape of the specimen and, perhaps, the available equipment or the operator's preference. It is always necessary, however, to remove sufficient metal to eliminate the effects of sawing, shearing, filing or whatever means was used in securing the specimen. For the softer alloys, cutting or grinding, as described later, will be satisfactory but alloys containing hard constituents should be prepared with a microtome or its equivalent.

(*c*) Lucas(31), who originated the method, used a Type K Jung microtome and recommends the rigid wood-sectioning instrument. Schumacher and Bouton(63), however, used an inexpensive biological microtome. In either case, the knife should be properly sharpened and should remove shavings not over three microns thick. Lead cable sheathing and other specimens are often prepared on a machinist's lathe, using a sharply pointed tool shaped to cut, and not flow, the metal. Cutting speeds and feeds should be slow. Still another method is to use a wood plane with a very sharp blade and set to remove the thinnest possible shaving. Samples to be prepared this way are generally clamped between two pieces of wood and the whole mass shaved down together.

(*d*) The methods described in Paragraph (*c*) are intended to produce a surface suitable for etching for low and high-power examination without further treatment and, when properly done, will produce surprisingly good results. A fine microtome surface is especially suitable for very fine work. A light etch will then produce a smooth surface.

(*e*) Bassett and Snyder(64) use a milled file to remove all traces of other working (saw marks, etc.) and to secure a flat surface. The surface is then ground smooth by hand on lubricated emery paper backed with plate glass. Although papers of various degrees of fineness may be used, Nos. 0 and 000 papers are usually sufficient. A new paper about thirty times the area of the surface of solid specimens and eight times the diameter of tube specimens should be used each time. Bumps or foreign particles on the paper are removed by scraping with a straight edge, while an abundant supply of gasoline or a solution of paraffin in kerosine is used as a lubricant. Grinding, with the specimen pressed firmly against the paper, is continued until the emery is worn smooth and a bright surface, free of prominent scratches, is obtained (5 to 7 min. on each paper). The specimen is etched after first wiping it free of gasoline or, if another lubricant was used, cleaning in gasoline and wiping. Such surfaces will usually show sufficient detail for examination at the magnifications generally used for lead. If, after etching, it appears that further preparation is desirable, grinding about 5 min. on Fischer No. 0000 emery paper may be helpful.

(*f*) Final fine polishing is not common practice with lead specimens but Vilella(65) recommends a suitable procedure. The specimen is polished wet on clean broadcloth liberally smeared with soap and using a water suspension of the finest levigated alumina. When a black smudge appears, polishing should be very carefully continued until it disappears and the surface is again bright. Scratches remaining after this operation are sometimes visible after etching but can be removed by alternately etching and polishing by hand on silk velvet well soaked with soap and alumina.

TABLE V.—ETCHING REAGENTS FOR LEAD AND ITS ALLOYS.

Etching Reagent	Composition		Remarks	Use
No. 1. Ammonium molybdate(**66**)	Molybdic acid (85 per cent) NH_4OH (sp. gr. 0.9) H_2O Filter and add to HNO_3 (sp. gr. 1.32)	100 g. 140 ml. 240 ml. 60 ml.	Alternately swab specimen and wash in running water.	Rapid etch; very suitable for removing thick layers of worked metal.
No. 2. Mixed acids(**64**)	Glacial acetic acid HNO_3 (conc.) H_2O	3 parts 4 parts 16 parts	Use freshly prepared solution at 40 to 42 C. (104 to 108 F.). Immerse 4 to 30 min. depending on depth of worked metal layer. Clean with wet cotton in running water.	Gives excellent detail for photographing.
No. 3. Mixed acids in glycerol(**65**)	Glacial acetic acid HNO_3 (conc.) Glycerol	1 part 1 part 4 parts	Use freshly prepared solution at 80 C. (176 F.).	Used for alternate polishing and etching.
No. 4. Ammonium molybdate-mixed acids(**64**)	See reagents Nos. 1 and 2.		Swab with reagent No. 1 until structure is clearly visible; immerse in reagent No. 2 for about 6 min.; clean by swabbing in running water.	Combines advantages of reagents Nos. 1 and 2.
No. 5. Acetic acid-hydrogen peroxide(**67**)	Glacial acetic acid H_2O_2 (9 per cent)	3 parts 1 part	Etch 10 to 30 min. depending on depth of worked metal layer; clean in concentrated HNO_3, if necessary.	Recommended for antimony alloys up to 2 per cent antimony(**6**).
No.5A. Acetic acid-hydrogen peroxide(**31,63**)	Glacial acetic acid H_2O_2 (30 per cent)	3 parts 1 part	Etch for 6 to 15 sec.	For lead-antimony alloys.
No. 5B. Acetic acid-hydrogen peroxide	Glacial acetic acid H_2O_2 (30 per cent)	2 parts 1 part	Etch 8 to 15 sec. by immersion.	For pure lead and lead-calcium alloys.
No. 6. Perchloric acid	$HClO_4$ H_2O	60 ml. 40 ml.	Electrolytic etching; specimen cathode, platinum anode.	Recommended for antimony alloys over 2 per cent antimony(**6**).
No. 7. Silver nitrate	$AgNO_3$ H_2O	5 to 10 g. 95 to 90 ml.	Use by swabbing.	For anti-friction metals.
No. 8. Nitric acid	HNO_3 (conc.) H_2O	50 ml. 50 ml.	Etch in boiling solution 5 to 10 min.	Macroscopic etching; welds, laminations, etc.
No. 9. Nitric acid(**68**)	HNO_3 (conc.).		Alternate in acid and running water.	Pure lead.

Etching Reagents

19. (*a*) In Table V are given etching reagents commonly recommended for lead and its alloys.

(*b*) Etching of lead is not wholly independent of the method of preparation but, in general, the reagent used to remove thick layers of worked metal will work universally, while the others may present some difficulties. The proponents of the microtome method of preparing specimens generally depend on a strong etchant to remove the layer of worked metal, although they find it occasionally desirable first to swab the specimen with the etchant to remove the heavier knife marks. When polishing is employed, the specimen is usually alternately polished on a velvet pad and lightly etched during the final stages until no further improvement is noted under the microscope.

Examination and Identification of Constituents

20. (*a*) After etching, the specimen must be properly dried to preserve the bright surface. This is generally accomplished by rinsing quickly and carefully in a full stream of running distilled water at or just below room temperature and quickly drying in a blast of air at or just below room temperature; excess liquid on the sides of the specimen may be removed by placing the surface gently on clean, dry blotting paper for about 5 sec. Specimens etched in certain reagents are somewhat difficult to dry properly, while some of the lead alloys are quite susceptible to tarnish. Warm, humid atmospheres also present extreme difficulty and may require the use of an alkali protective film(**63**) or examination while the specimen is submerged in water.

(*b*) Lead may be examined for defects at a magnification of 5 to 15 diameters, but for fine grain structure should be examined at 50 to 75 diameters. Photographs at the low magnifications are taken on regular plates, using either vertical or oblique lighting and, sometimes, a Wratten K2 filter; at the higher magnifications panchromatic plates and a Wratten E (No. 22) filter are recommended.

(*c*) Lead-tin alloys are usually examined at 75 to 100 diameters and lead-antimony alloys at 100 to 200 diameters. Photographs can be taken with regular plates and the Wratten K2 filter.

MAGNESIUM AND ITS ALLOYS(**70,71**)

Preparation of Specimens

21. (*a*) In general, the preparation of magnesium and magnesium alloy specimens is similar to the preparation of aluminum specimens. Sulfur is recommended as the mounting material for specimens too small to handle unmounted, as it is cheap, light, easy to handle and exerts no

galvanic action on the metal during polishing and etching operations. The procedure described in Paragraphs (*b*) and (*c*) is generally recommended for developing the best results with magnesium but is not necessarily the only satisfactory method.

(*b*) As in the preparation of aluminum specimens, a plane surface can be secured with a microtome; otherwise, grinding successively on aloxite cloths Nos. 50, 100, and 150 is recommended. The grinding is then finished by successive use of Nos. 0, 000 and 0000 metallographic emery paper. For convenience, the abrasive cloths or papers may be mounted on disks rotating at 800 to 1200 r.p.m.

(*c*) Polishing is carried out in three stages; the first two commonly referred to as "rough polishing" and the third as "fine polishing." The rough polishing is usually done on velvet or "vel-chamee" cloths mounted on disks rotating at 500 to 600 r.p.m. In the first stage the abrasive is usually XF alundum and in the second it is No. 600 alundum; in both, only enough distilled water is used to prevent seizure of the specimen. Fine polishing is accomplished on a velvet-covered disk rotating at 100 to 400 r.p.m. and moistened with a suspension of specially levigated alumina (Note). Seizure is prevented by using a small amount of filtered liquid soap on the wheel. After polishing, the specimen is rinsed in water, then in acetone or alcohol, and dried in a blast of warm air.

TABLE VI.—ETCHING REAGENTS FOR MAGNESIUM AND ITS ALLOYS.

Etching Reagent	Composition	Remarks	Use
No. 1. Acetic acid..........	10 per cent aqueous solution.	Swab with cotton for $\frac{1}{2}$ to 2 min.	Macroetching.
No. 2. Oxalic acid..........	2 per cent aqueous solution.	Swabbing for 2 to 5 sec.	Cast and wrought magnesium and most alloys in cast form.
No. 3. Nitric acid...........	2 per cent aqueous solution.	Swabbing.	To develop coring and for etching some casting alloys.
No. 4. Malic acid - nitric acid..................	Aqueous solution, 5 per cent malic and 2 per cent nitric acids.	Etch 10 to 30 sec.	For wrought alloys.
No. 5. Tartaric acid........	2 per cent aqueous solution.	Etch 10 to 20 sec.	For magnesium-manganese wrought alloys and cast and heat-treated magnesium-aluminum-manganese-zinc alloys.

NOTE.—The specially levigated alumina recommended for fine polishing can be easily prepared by placing 150 g. of the best commercial levigated alumina and 2 liters of 0.001 *N* sodium hydroxide in a 4-liter bottle and agitating (by a stream of compressed air) for 1 hr. Two more liters of the 0.001 *N* sodium hydroxide are then added and the mixture shaken thoroughly. After standing for 24 hr., the upper 8 in. of supernatant liquor are carefully siphoned off, yielding the solution for fine polishing. The sediment can be reworked several times, yielding additional solution.

Etching Reagents

22. In Table VI are given the etching reagents commonly recommended for magnesium and its alloys.

Examination and Identification of Constituents

23. (*a*) As is suggested in the description of etchants (Table VI), visual or low power macroexamination is usually made on specimens etched for ½ to 2 min. in a 10 per cent acetic acid solution (reagent No. 1). For such examination the polishing need not be as carefully done as is necessary for microexamination, where etching is usually done in dilute acids and for short times in order to secure the necessary detail and avoid coring. Although the etchants shown in Table VI are the ones most commonly employed, numerous acids—both organic and inorganic—are equally successful. In all cases, etched specimens should be rinsed in running water, then in acetone or alcohol, and dried in a blast of warm air.

TABLE VII.—MICROSCOPIC IDENTIFICATION OF CONSTITUENTS IN SAND-CAST MAGNESIUM ALLOYS.

Element		Detection		Unetched		Etched 2 to 5 sec. in 2 per cent Oxalic Acid	
		Optimum Condition	Approximate Minimum, per cent	Shape	Color	Shape	Color
Aluminum in	Alloys	etched	2.0	......	......	globular[e]	white
	Magnesium	etched	2.0	......	......	globular[e]	white
Cadmium[a] in	Alloys	......	......	......	......	......	......
	Magnesium	......	......	......	......	......	......
Copper in	Alloys[b]	etched	0.5	......	......	globular	gray
	Magnesium	etched	0.5	......	......	network[e]	iridescent
Iron in	Alloys[b]	unetched	0.03	globular[e]	black	globular[e]	black
	Magnesium	unetched	0.03	rectangular	black	rectangular	black
Manganese in	Alloys[b]	unetched	0.1	rounded[c]	dark gray	rounded[c]	dark gray
	Magnesium	unetched	0.1	rounded[c]	dark gray	rounded[c]	dark gray
Nickel in	Alloys[b]	etched	0.5	globular	gray	globular[c]	dark gray
	Magnesium	etched	0.3	network	gray	network[c]	dark gray
Silicon in	Alloys[b]	unetched	0.03	globular	gray	globular[d]	gray
	Magnesium	unetched	0.03	network	gray	network[f]	black

(*Courtesy: The Dow Chemical Co.*)

[a] Cadmium is completely soluble in magnesium and its alloys and forms no microscopically visible constituent.
[b] In magnesium-manganese alloys the microscopic constituents appear as in pure magnesium.
[c] Outlined.
[d] Partially dissolved.
[e] Pitted.
[f] Dissolved.

(*b*) Table VII outlines a method for identifying metallic constituents in sand-cast materials. In the heat-treated or wrought alloys the identification differs slightly, chiefly because of the increased solubility of certain constituents or to spheroidizing and breaking up of constituents by heat treating or plastic deformation. The table indicates the condition (etched or unetched) under which the constituent is best identified, the minimum amount which can readily be detected, and the usual appearance. Many of the constituents appear in a "globular form" when present in small amounts but take a network form when larger amounts are involved. This transformation may occur with a change of a few tenths per cent of the element, or it may require a change of as much as 10 per cent for development.

NICKEL AND ITS ALLOYS

Preparation of Specimens

24. The specimen is first ground on a series of abrasive papers of increasing fineness, such as French Nos. 0, 00, and 000 or carborundum Nos. 240, 320 and 400, mounted on wheels revolving at 400 to 600 r.p.m. A final grinding on a paper made by graphiting a sheet of the French No. 000 or carborundum No. 400 paper is frequently inserted prior to wet polishing and, if done, eliminates the one wet polishing operation. When this fine paper is omitted, wet polishing is begun with a water suspension of No. 600 alundum on a broadcloth-covered wheel rotating at 500 to 800 r.p.m. This is followed by a few seconds' polishing with a water suspension of levigated alumina (settled at $\frac{1}{4}$ in. per hr.) on a wheel covered with broadcloth or flat silk crepe. The procedure employing the graphited paper and a crepe covering on the final wheel is useful in retaining inclusions and largely avoids pitting and surface flow.

TABLE VIII.—ETCHING REAGENTS FOR NICKEL AND ITS ALLOYS.

Etching Reagent	Composition		Remarks	Use
No. 1. Flat solution **(72)**	HNO_3 (conc.) Glacial acetic acid	50 ml. 50 ml.	Make up fresh daily; use clear white HNO_3 to avoid staining; etch by immersion at room temperature for 5 to 20 sec.	Nickel, Monel metal and other nickel-copper alloys. Dilute with 25 to 50 per cent acetone for alloys of less than 25 per cent nickel.
No. 2. Electrolytic contrast **(72)**	Glacial acetic acid H_2O HNO_3	5 ml. 85 ml. 10 ml.	Electrolytic etch for 20 to 60 sec. using 1.5 v. dry cell and platinum wires.	Very satisfactory for grain-size studies. Stains less than flat solutions.
No. 3. Nitric acid	HNO_3 (conc.) H_2O	30 ml. 70 ml.	Etch by immersion.	Macroetch for nickel silver.
No. 4. Potassium cyanide	KCN H_2O H_2O_2	5 g. 95 ml. few drops.	Etch by immersion.	For low-zinc nickel silver.
No. 5. Ammonium hydroxide - hydrogen peroxide	NH_4OH H_2O_2	85 ml. 15 ml.	Etch by immersion.	For high-zinc nickel silver.

Etching Reagents

25. (*a*) In Table VIII are given the etching reagents commonly recommended for nickel and its alloys.

(*b*) Etched specimens should be thoroughly washed with water and alcohol and dried in an air blast. Stains can be removed by wiping with a clean, smooth cloth or cotton.

PRECIOUS METALS

Preparation of Specimens

26. (*a*) Specimens of the precious metals are all prepared in about the same way as the more common metals. A plane surface is first secured with a flat, single-cut file, after which the surface is ground successively

TABLE IX.—ETCHING REAGENTS FOR THE PRECIOUS METALS.[a]

Etching Reagent	Composition		Remarks	Use
No. 1. Potassium cyanide - ammonium persulfate[b] . . .	*A*. KCN (5 per cent solution)	1 part	*A*. Etch 1 to 2 min.	*A*. Pure silver.
	$(NH_4)_2 S_2O_8$ (5 per cent solution)	1 part		
	B. KCN (10 per cent solution)	1 part	*B*. Addition of 2 per cent KI will produce more rapid attack. Etch ½ to 3 min. Make up fresh each time.	*B*. Gold.
	$(HN_4)_2 S_2O_8$ (10 per cent solution)	1 part		
	C. KCN (20 per cent solution)	1 part	*C*. 3 per cent KI may be added.	*C*. A slow etch for palladium or the complicated dental alloys.
	$(NH_4)_2 S_2O_8$ (20 per cent solution)	1 part		
No. 2. Chromate **(73)**	*A*. HNO_3 (1:1)	100 ml.	Dilute *A* to 20 vol., add equal amount of *B*. Apply with camel's hair brush. Non-adherent film of red, silver chromate should form. If film adheres, add more of *A*; if none forms, add *B*.	Used for silver alloys.
	$K_2Cr_2O_7$	2 g.		
	B. H_2CrO_4	20 g.		
	Na_2SO_4	1.5 g.		
	H_2O	100 ml.		
No. 3. Chromic acid - sulfuric acid **(74)**.	Aqueous solution, 0.2 per cent each H_2CrO_4, and H_2SO_4.		Etch 1 min.	Silver alloys.
No. 4. Electrolytic etching **(75)**	*A*. 1 per cent solution of HF plus small amount of stannous chloride.			(*A*) Used for silver-tin alloys with over 73 per cent silver.
	B. Dilute solutions of HCl, KCN or KCN+KI **(76)**.			(*B*) Occasionally used for gold.
No. 5. Iodine	50 per cent solution of U.S.P. tincture of iodine in aqueous KI solution.		Film of silver-iodide may remain on surface of gold-silver alloys; can be removed with KCN solution.	Gold alloys.
No. 6. Aqua regia . .	*A*. Slightly dilute.		*A*. Etch 5 min. in warm solution.	*A*. Pure platinum.
	B. Concentrated.		*B*. Use hot.	*B*. Platinum alloys. Also used for gold alloys but will form chloride film when much silver is present. Ammonia or KCN will remove film.
	C. In glycerine.		*C*. Use cold.	*C*. Palladium alloys.
No. 7. Potassium sulfide **(77)**	. . . .		Use hot.	Gold-nickel alloys.
No. 8. Fused salts . .	KOH+10 per cent KNO_3 or $KHSO_4$.		Etch in fused salt.	Used for platinum if aqua regia is ineffective.
No. 9. Nitric acid	Concentrated.		Use hot.	Palladium.
No. 10. Ammonium hydroxide - hydrogen peroxide	NH_4OH	5 parts	Immersion.	For silver or silver-palladium alloys.
	H_2O_2	1 to 3 parts		

[a] See also **(78,79)**.

[b] Developed for a somewhat different purpose by M. C. Jewett.

on Nos. 240, 280, 320 and 400 grain Aloxite paper and Nos. 000 or 0000 Hubert paper (previously smoothed by rubbing with a bit of hardened steel).

(*b*) The specimen is then polished on a felt wheel using No. 600 alundum and kept well moistened. The final polish is secured with a velvet or velveteen wheel using finely divided magnesia (as a water paste) or levigated alumina (settled at the rate of $\frac{1}{4}$ in. per hour). When magnesia is used, the usual precautions to avoid carbonate formation must be followed.

Etching Reagents

27. In Table IX are given the etching reagents commonly recommended for the precious metals.

TIN AND ITS ALLOYS

Preparation of Specimens

28. (*a*) These metals are in a class with lead and its alloys and may advantageously be prepared similarly. Tin and its softer alloys may be prepared by microtoming but the harder alloys may require one or two polishing steps before etching. Alternate polishing and etching is frequently desirable.

(*b*) Specimens may be smoothed on a lathe with a tool having a sharp, smooth cutting edge and large clearance, followed by polishing on Manning emery papers from Nos. 0 to 000, lubricated with paraffin dissolved in kerosine. After the operation is completed on each paper, the specimen may be etched with HCl (10 to 20 per cent), or other solution as required, for a short time to remove any metal that may have been flowed on the polished surface. The specimen is then polished on a broadcloth-covered wheel, using a solution of soap and levigated alundum grain. The specimen is then again etched and finally polished on a second wheel covered with high-grade silk velvet using the same polishing medium as for the broadcloth. Alternate polishing and etching will be required to bring out the structure satisfactorily**(65)**.

(*c*) A solution of paraffin and kerosine may be prepared by dissolving 100 g. of paraffin and 200 ml. of warm kerosine. The solution of soap and levigated alundum grain may be prepared as follows: 5 g. of alundum grain (Norton size No. 600 grain) added to 300 ml. of water. After thorough agitation, the mixture is permitted to stand for 15 min., whereupon the supernatant suspension is decanted. To this decanted suspension, 40 g. of soap are added and the mixture heated until the soap is dissolved. Both mixtures are nearly solid at room temperature, so that it is necessary to use them warm. To remove the paraffin before etching, the samples are washed in warm kerosine and the kerosine is removed by washing the specimen with soap and water. The soap film may be dried on or removed in a strong stream of warm water(81).

Etching Reagents

29. In Table X are given the etching reagents commonly recommended for tin and its alloys.

TABLE X.—ETCHING REAGENTS FOR TIN AND ITS ALLOYS.

Etching Reagent	Composition		Remarks	Use
No. 1. Nital	HNO_3 C_2H_5OH	2 to 5 ml. 95 to 98 ml.	Swab or immerse for several minutes.	Tin-cadmium or tin-iron alloys.
No. 2. Potassium dichromate	Acidified, dilute solution.			Tin-cadmium alloys.
No. 3. Mixed acids in glycerol(67)	*A.* HNO_3 Acetic acid Glycerol	1 part 1 part 8 parts	Immerse $\frac{1}{2}$ to 10 min. at 38 to 42 C.	*A.* Tin-lead alloys.
	B. HNO_3 Acetic acid Glycerol	1 part 3 parts 5 parts	Same as for *A*, above.	*B.* Pure tin.
No. 4. Hydrochloric acid	*A.* HCl (conc.).		*A.* Immerse for several seconds.	*A.* To remove surface flow.
	B. HCl H_2O	10 to 20 ml. 90 to 80 ml.	*B.* Immerse $\frac{1}{2}$ to 5 min. following *A*.	*B.* Follows *A*.
	C. HCl H_2O	10 ml. 90 ml.	*C.* Electrolytic etch at low current density.	*C.* Tin-iron alloys.
No. 5. Ferric chloride	$FeCl_3$ HCl H_2O	10 g. 2 ml. 95 ml.	Immerse $\frac{1}{2}$ to 5 min. at room temperature.	Microetching tin-rich babbit metal.
No. 6. Nitric and picric acids	Alcoholic solution.			Tin-iron alloys.
No. 7. Ammonium(80) polysulfide	Concentrated solutions.		Immerse 20 to 30 min. at room temperature.	Macroetching of tin-rich babbit metals.

Solutions of silver nitrate or 10 per cent nitric acid plus 5 per cent chromic acid are also occasionally used.

ZINC AND ITS ALLOYS

Preparation of Specimens

30. (*a*) There are two facts which must be kept in mind when preparing zinc specimens, particularly the purer grades of zinc. (*1*) Mechanical twins are readily formed, especially in coarse-grained zinc. These may be formed during the polishing operation and care must be taken to remove a sufficient depth of metal in subsequent operations to cut beneath the distorted layer. (*2*) The recrystallization temperature of commercial zinc may range from 100 C. (212 F.) to as low as room temperature for the purest zinc. Care is, therefore, needed to avoid unduly heating the specimen during grinding or polishing operations.

(*b*) After mounting, the specimen is ground on a belt sanding machine, using successively belts of about the following grades: Nos. 30, 50, 120 and 320. It is advisable to dip the specimens in water occasionally to avoid heating. At least $\frac{1}{16}$ in. of the surface of the section should be removed in these four operations so that the distortion produced at the sheared or sawed edges of the specimen may be removed. If the sanding machine is not available, a mill file may be substituted.

(*c*) Dry polishing is carried out on four grades of emery paper, Nos. 1, 0, 00, 000, resting on plate glass. Each succeeding operation should be carried out at an angle to the preceding operation. Merely removing the scratches from the preceding operation is not sufficient; experiments have shown that polishing distortion (as shown by the presence of twin bands after etching) may be found to depths of at least twenty times the depth of the deepest scratch in some cases. Therefore, when all preceding scratches have been removed, polishing should be continued for a time. Since there is no method of judging the depth of distortion for a given specimen, the amount of polishing must be gaged largely by experience. It may be said, however, that coarse-grained pure zinc is most easily distorted while fine-grained material, particularly alloys, will give little trouble from this source except possibly in the final stages of polishing.

(*d*) Wet polishing is carried out on four cloth-covered wheels, rotating from 200 to 400 r.p.m. The first two are covered with white duck, the last two with broadcloth or billiard cloth. Rodda(14) has described a suitable method for preparing abrasives for use on the four wheels, but those suitable for aluminum and magnesium can be used. Care is also needed in wet polishing to remove the distortion produced by the preceding operation. The amount of metal removed during wet polishing is slight and it is more feasible to remove the bulk of the distorted metal by etching with the Palmerton reagent. The following schedule is recommended:

Etch $3\frac{1}{2}$ min.
Polish on No. 1 wheel
Etch $1\frac{1}{2}$ min.
Polish on No. 2 wheel
Etch 30 sec.
Polish on No. 3 wheel
Etch 10 sec.
Polish on No. 4 wheel
Etch 3 sec.

(*e*) The etching schedule may be varied somewhat depending upon the specimen and the purpose of the examination. For examination at low magnification polishing may generally be stopped at the third wheel. When the oil immersion objective is to be used, the etching time after the fourth wheel should generally be reduced to 1 sec., particularly if there are constituents present which are unattacked by the etching reagent. Otherwise, the difference in elevation between etched and unetched constituents will make it impossible to bring both into focus at one time. When polishing specimens containing constituents of widely varying hardness and etching characteristics, such as galvanized iron or plated zinc, alternate polishing and etching is not advisable as the etched structure is not completely removed during the subsequent polishing due to the nap of the cloth.

(*f*) Care must be taken to avoid carrying coarse abrasive to a finer wheel. The best means of avoiding this is to wash both hands and specimen with soap and water between polishing operations on the wheels. Dragging out of inclusions or cavities may be minimized by occasionally rotating the specimen 180 deg. or even by continuously rotating the specimen.

Etching Reagents

31. (*a*) In Table XI are given the etching reagents commonly recommended for zinc and its alloys.

TABLE XI.—ETCHING REAGENTS FOR ZINC AND ITS ALLOYS.

Etching Reagent	Composition		Remarks	Use
No. 1. Palmerton reagent(82,83)........	CrO_3 (99.95 per cent)..... Na_2SO_4 (c.p.)............ H_2O....................	200 g. 15 g. 1000 ml.	Immersion with gentle agitation. Follow with rinse in solution of: CrO_3 200 g. H_2O 1000 ml.	General. (Reduce Na_2SO_4 to 7.5 g. when using solution to develop grain structure in alloys containing copper.)
No. 2. Hydrochloric acid................	HCl.................... Ethyl alcohol...........	5 ml. 95 ml.	Immersion for 2 to 3 sec.	Contrast between die casting and plated coatings.
No. 3. Hydrochloric acid................	HCl (conc.)			Macrostructure of pure zinc.

(*b*) The Palmerton reagent is the most widely used etching solution for zinc alloys; it is followed by the rinse in the chromic acid solution to avoid staining.

Examination and Identification of Constituents

32. After polishing is completed, the finger dipped in alcohol is rubbed lightly over the surface of the specimen to remove any slight film of abrasive. The specimen is then rinsed successively in alcohol, ether, alcohol, and water, the excess water shaken off and immersed in the etching solution. After etching, the specimen is thoroughly rinsed successively in water, alcohol, and ether and dried in a blast of warm air. Nothing should touch the etched surface as it is sometimes delicate and easily scratched. To avoid tarnishing, specimens should be kept in a desiccator until photographed.

MICROSCOPY AND PHOTOGRAPHY

Microscopy and Photography

33. (*a*) Recommendations governing the preparation of micrographs and photographic practice are given in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended

Practice for Photography as Applied to Metallography (A.S.T.M. Designation: E 2) of the American Society for Testing Materials.[1] These deal with the standard magnifications, lens combinations, methods of determining grain size, illumination, and photographic materials.

(*b*) *Illumination.*—Lord(84) has given a good account of the use of vertical illumination in low-power photography. For microscopic work vertical illumination is customary and preferable, although "conical" illumination(85) and dark field illumination (in which the ordinarily darker constituents, like inclusions, appear lighter against a darker background) may be useful for special purposes. Polarized light has been used in the examination of non-ferrous alloys(86,87,88) and in one instance at least to aid in revealing the structure of steel(87). It can be used in studying nonmetallic inclusions. Ultra-violet radiation has been tried(90,91), but thus far has found very limited use.

Preservation of Surface

34. To preserve the surface of deeply etched specimens, they should be thoroughly washed to remove all traces of acid, dried, and painted with transparent metal lacquer or rubbed in with oil or soap solution. If a light repolishing prior to later examination is not objectionable, the specimens of many non-ferrous alloys need not be protected but should be carefully washed and dried. Touceda(92) recommends wrapping samples for microscopic examination in cellophane tubes to preserve them. A simple and effective procedure is to wrap them in ordinary writing paper and keep them in a dry place.

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TENTATIVE METHOD OF TEST

FOR

QUANTITATIVE SPECTROCHEMICAL ANALYSIS OF HIGH GRADE PIG LEAD FOR COPPER, BISMUTH, SILVER AND NICKEL[1]

A.S.T.M. Designation: E 25 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method[3] may be applied to any high grade of lead, provided the impurities, namely, copper, silver, bismuth and nickel are not present in quantities over 0.1 per cent. Iron is seldom found and then it is a question whether it was originally in the sample. An arc spectrum is used, employing graphite electrodes, one of which is treated with a solution of the sample to be analyzed. Quantitative estimations are made by the comparison of the spectrum of the sample with the spectra of standard samples of known composition.

Preparation of Sample Solution

2. A 20-g. portion of turnings, or filings, from a representative sample of the pig lead to be analyzed shall be weighed and then dissolved in a solution of 20 ml. of nitric acid and 80 ml. of distilled water. The solution shall be gently warmed until a perfectly clear solution results. After the sample has gone completely into solution, sufficient distilled water shall be added to bring the volume to exactly 100 ml. at room temperature, and the solution transferred to a small glass-stoppered bottle. Each 0.1 ml. of this solution will contain 0.02 g. of sample. This procedure shall be repeated, thus making available duplicate sample solutions.

Preliminary Estimation

3. (*a*) Fifty milligrams of filings of the lead sample shall be introduced into a recessed graphite electrode (Note 1). This electrode shall be made the lower and positive member of a pair of electrodes, between which an

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee E-2 on Spectrographic Analysis.

[2] Accepted for publication as tentative by Committee E-10 on Standards, October 7, 1935.

[3] The procedure is based upon the technique of spectrographic analysis as described by C. C. Nitchie, "Quantitative Analysis with the Spectrograph," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 1, p. 1 (1929).

electric arc shall be created by applying a potential of 60 to 70 v. with a direct current of 15 amp. The spectrum of the arc shall be recorded (Note 2) by means of a spectrograph from the moment the arc is struck until the arc has burned for 3 min. The plate thus obtained shall be referred to as the preliminary plate.

(*b*) The preliminary plate shall be compared with a standard plate on which are recorded the spectra of filings of a metal of known impurity content. By visual comparison of the blackness of the spectral lines (Note 4) of the impurities in the spectrum of the sample with the corresponding lines in the standard spectra, the approximate impurity content of the sample shall be ascertained.

Final Estimation

4. (*a*) The final estimation of the impurity content shall be made by comparison of spectral exposures of a solution of the sample (Section 2) with spectral exposures of standard solutions (Note 3), all of which are photographed on one plate. By using alternate standard and sample solutions, with the standards selected having graded impurity contents, a very close estimation of the impurity content may be obtained. A typical procedure will be as follows: Three standard solutions shall be selected; that is, a high, a medium and a low standard, respectively. The standards to be selected will be indicated from the preliminary estimation of the composition of the sample (Section 3). A 0.1 ml. of each standard solution shall be introduced individually into recessed electrodes, one electrode for each solution. Two 0.1-ml. portions of one of the sample solutions shall be introduced individually into recessed electrodes. The electrodes shall be dried in an oven at 200 F. (93 C.) for about 30 min.

(*b*) Two spectral plates[a] shall be prepared each having five 3-min. exposures (excitation of spectra described under Section 3 (*a*)) in the following order:

First spectral exposure	Low standard
Second spectral exposure	Sample
Third spectral exposure	Medium standard
Fourth spectral exposure	Sample
Fifth spectral exposure	High standard

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[a] The ten exposures may be recorded on one plate rather than two plates of five exposures each.

The plate shall be adjusted for each exposure so that the spectral exposures are in juxtaposition, for ease of comparison with one another.

(*c*) From the finished plates, the impurity content shall be estimated on the basis of a visual comparison of the difference in blackness between the various characteristic spectral lines photographed in the five exposures as outlined above. Two observers should independently evaluate the plates and their estimations should check.

(*d*) If the four impurities are within the limits of the high and low standards used, all four impurities may be determined from the same plates. If, however, this cannot be done, it will be necessary to repeat the spectrography[1] for the impurities not covered by the above plates, using standards suitable for the undetermined impurities.

TESTING FOR COMPLIANCE WITH SPECIFICATIONS

5. Frequently, the object of the spectrographic inspection is merely to determine whether the impurity contents are more than certain specified amounts, as in the case of specification requirements on the composition. For this purpose the analytical procedure described in Sections 2 to 4 may be considerably simplified. The procedure described in Section 6 was developed so as to include the testing of a number of samples on one spectral plate.

Procedure

6. (*a*) *Standard Solution.*—One standard solution containing the maximum impurity contents allowed by the specifications shall be prepared to a concentration of 0.2 g. of metal per milliliter of dilute nitric acid (20 per cent nitric acid by volume).

(*b*) *Sample Solution.*—Duplicate solutions of each sample shall be prepared as described in Section 2.

(*c*) *Preparation of Spectra.*—Electrodes containing sample or standard solutions shall be prepared according to the procedure described in Section 4 (*a*) and their spectra shall be photographed according to the method given in Section 3 (*a*). The following order of spectral exposures shall be used, the several samples to be tested being distinguished by numbers:

First spectral exposure	No. 1 sample
Second spectral exposure	Standard
Third spectral exposure	No. 2 sample
Fourth spectral exposure	No. 3 sample
Fifth spectral exposure	Standard
Sixth spectral exposure	No. 4 sample
Seventh spectral exposure	No. 5 sample
Eighth spectral exposure	Standard
Ninth spectral exposure	No. 6 sample

(*d*) A second or duplicate plate shall be made in the same manner, using the duplicate sample solutions.

(*e*) By visual comparison of the blackness of the spectral lines (Note 4) of the impurities of the standard spectra with the corresponding lines of the spectra of the sample, a determination may be made as to whether the composition of the sample is within the limits set by the specifications.

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[1] It is not the intent of this method to limit to three the number of standards whose spectra are recorded on one plate. If it is necessary to use more than three standards for the analysis of one sample, the spectra of more than three may be photographed on one plate. The essential requirements are that the standard spectra be alternated with spectra of the sample and that at least two sample spectra be recorded from each sample solution.

EXPLANATORY NOTES

NOTE 1: *Electrodes.*—The electrodes shall be prepared from high-purity graphite rods, $\frac{5}{16}$-in. diameter being recommended (found by test to be free from copper, bismuth, silver and nickel). The electrodes which are to contain the sample shall be cut into 2-in. lengths and recessed at one end by drilling an axial hole about 0.15 in. in diameter and 0.25 in. in depth. Prior to use the electrodes shall be burned in a 10-amp. arc for about 2 min., by which treatment any impurities with which the electrodes may have been contaminated in the handling are volatilized.

NOTE 2: *Spectrography.*—The spectrograph shall have quartz optics or a diffraction grating of sufficient resolving power and dispersion to separate clearly the lines of the constituents to be determined from the lines of other elements present in the spectrum of the sample. In illuminating the slit of the spectrograph with the light from the arc, a quartz condensing lens (or lenses) shall be used in such a manner that the images of the electrode tips are sharply defined, one above, the other below, the open portion of the slit, in order to exclude the intense continuous spectrum of the hot carbon electrodes from the spectrograph. Adjustment of the distance between the electrodes shall be made, from time to time, in order to compensate for the burning away of the electrode tips. The same portion of the slit shall be used throughout, preferably the central portion. A moderately slow, fine-grained photographic plate is best suited for this method. Eastman 33 plate is an example of this type of plate. The following developer formula is suggested:

Stock Solution A:	
Water	1000 ml.
Hydroquinone	42 g.
Anhydrous sodium sulfite	85 g.
Potassium bromide	3 g.
Citric acid	1.2 g.

Stock Solution B:	
Water	1000 ml.
Anhydrous sodium carbonate	150 g.

For use take 100 ml. of Solution *A*, 80 ml. of Solution *B* and 420 ml. of water. Develop 4½ min. at 70 F. (21 C.). After development, the plate shall be washed, fixed and dried.

NOTE 3: *Standard Solutions.*—Nitric acid solutions of pure lead, with known amounts of added impurities shall be used for standard solutions. A uniform concentration of 0.20 g. of metal per milliliter shall be maintained.

The preparation of such solutions shall be as follows:

Solution A (Lead Stock Solution).—300 g. of pure lead[1] shall be dissolved in 285 ml. of nitric acid (sp. gr. 1.42) and 1200 ml. of distilled water. After the sample has been dissolved, the solution shall be allowed to cool and the volume shall be adjusted to 1500 ml. This solution will contain 0.2 g. of lead in each milliliter.

Solution No. 1 for Copper.—0.64 g. of copper shall be dissolved in the least amount of dilute nitric acid (50 per cent nitric acid by volume) and the resulting solution shall be evaporated to a small volume of about 2 ml.

19.36 g. of pure lead shall be placed in a 200-ml. flask and dissolved in 18 ml. of nitric acid (sp. gr. 1.42) and 75 ml. of distilled water.

The two solutions shall be combined and the volume of the resulting solution shall be adjusted to 100 ml. at room temperature.

Solutions No. 2 for Bismuth, No. 3 for Silver and No. 4 for Nickel.—Three additional solutions shall be made in an identical manner to Solution No. 1 except that the copper shall be replaced by bismuth, silver and nickel, respectively.

Solution B.—40 ml. of Solution No. 1, 16 ml. of Solution No. 2, 8 ml. of Solution No. 3 and 8 ml. of Solution No. 4 shall be combined and to the resulting solution shall be added a sufficient quantity of Solution *A* to make 200 ml. of solution. This solution (Solution

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[1] The lead shall not contain any impurity in an amount which will significantly alter the blackness of the spectral lines of copper, bismuth, silver and nickel. The contents of copper, bismuth and silver should be less than 0.0001 per cent each and the nickel content, less than 0.0002 per cent.

B) will contain 0.64 per cent copper, 0.256 per cent bismuth, 0.128 per cent silver and 0.128 per cent nickel.

Solution C.—Solution *C* shall be obtained by using 100 ml. of Solution *B* and 100 ml. of Solution *A* and thoroughly mixing to insure a uniform solution. This solution will contain 0.32 per cent of copper, 0.128 per cent of bismuth, 0.064 per cent of silver and 0.064 per cent of nickel.

The succeeding lower standards shall be made in the same manner and may be continued to any desired low limit or to the vanishing point:

STANDARD SOLUTIONS	COPPER, PER CENT	BISMUTH, PER CENT	SILVER, PER CENT	NICKEL, PER CENT
B	0.64	0.256	0.128	0.128
C	0.32	0.128	0.064	0.064
D	0.16	0.064	0.032	0.032
E	0.08	0.032	0.016	0.016
F	0.04	0.016	0.008	0.008
G	0.02	0.008	0.004	0.004
H	0.01	0.004	0.002	0.002
I	0.005	0.002	0.001	0.001

Other combinations, with varying percentages of impurities can easily be prepared to suit particular problems.

NOTE 4: *Spectral Lines.*—The lines used in evaluating the plate shall not be too black, since the very black lines do not show much change in appearance with change in concentration of the corresponding element.

The following table lists suitable lines for the estimation of copper, bismuth, silver and nickel in pig lead, together with an indication of the approximate range of concentration in which the line is useful:

ELEMENTS TO BE DETERMINED	WAVE LENGTH IN INTERNATIONAL ANGSTROMS OF SUITABLE LINES	RANGE OF CONCENTRATION IN WHICH LINE IS USEFUL, PER CENT
Copper	2492.15 2618.38 2766.39 2961.18	0.32 to 0.04
Bismuth	3247.55 3273.96	0.04 to 0.0001
	2897.98 2989.04 2993.34 3024.64	0.256 to 0.02
Silver	3067.73	0.02 to 0.001
	3280.67 3382.89	0.128 to 0.0001
Nickel	3002.49 3003.63	0.128 to 0.001

TENTATIVE METHOD OF TEST
FOR
QUANTITATIVE SPECTROCHEMICAL ANALYSIS OF ZINC FOR LEAD, IRON AND CADMIUM[1]

A.S.T.M. Designation: E 26 – 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method[3] may be applied to any grade of zinc providing the lead, iron and cadmium contents are less than 0.1 per cent. An arc spectrum is used, employing graphite electrodes, one of which is treated with a solution of the sample to be analyzed. Quantitative estimations are made by the comparison of the spectrum of the sample being analyzed with the spectra of standard samples of known composition.

Preparation of Sample Solution

2. A 20-g. portion of a representative sample of the zinc to be analyzed shall be weighed, placed in a 250-ml. beaker and dissolved in hydrochloric acid (Note 1). If the volume of the solution is greater than 35 ml., it shall be evaporated to approximately 35 ml., cooled, transferred to a 50-ml. graduate, distilled water added to bring the volume to 40 ml. and the solution transferred to a small glass-stoppered bottle. This procedure shall be repeated, thus making available duplicate sample solutions.

Preparation of Electrode

3. A 0.1 ml. of one of the sample solutions shall be introduced into a recessed graphite electrode (Note 2). Directly after the introduction of the solution, the electrode shall be dried in an oven at 200 F. (93 C.) for about 30 min.

Preliminary Estimation

4. (*a*) The electrode containing the sample solution shall be made the lower and positive member of a pair of electrodes between which an

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee E-2 on Spectrographic Analysis.

[2] Accepted for publication as tentative by Committee E-10 on Standards, October 7, 1935.

[3] The procedure is based upon the technique of spectrographic analysis as described by C. C. Nitchie, "Quantitative Analysis with the Spectrograph," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 1, p. 1 (1929).

electric arc shall be created by applying a potential of 80 to 100 v. with a direct current of 10 amp. The spectrum of the arc shall be recorded (Note 3) by means of a spectrograph from the moment the arc is struck until the arc has burned for 2 min. The plate thus obtained shall be referred to as the preliminary plate.

(*b*) The preliminary plate shall be compared with a standard plate (Note 4) on which are recorded the spectra of the standard solutions (Note 5). By visual comparison of the blackness of the spectral lines (Note 6) of lead, iron and cadmium in the spectrum of the sample with the corresponding lines in the standard spectra, the approximate impurity content of the sample shall be ascertained.

Final Estimation

5. (*a*) The final estimation of the impurity content shall be made on the basis of plates on each of which are photographed two spectral exposures of the sample and three standard spectral exposures. Beginning with one impurity, for example, lead, three standards of various lead contents, a high, a medium and a low content, respectively, shall be selected. The medium standard shall be that which is nearest to the lead content of the sample as estimated from the preliminary plate (Section 4). Six recessed electrodes (Note 2) shall be treated (Section 3) with 0.1-ml. portions each of the standard solutions, preparing two electrodes for each of the three standards. Four electrodes shall be treated with 0.1 ml. each of the sample solutions, preparing two electrodes from the one sample solution and two from the duplicate sample solution. The electrodes shall be dried in an oven at 200 F. (93 C.) for about 30 min.

(*b*) Two spectral plates[a] shall be prepared each having five 2-min. exposures (Section 4 (*a*)) in the following order:

First spectral exposure	Low standard
Second spectral exposure	Sample
Third spectral exposure	Medium standard
Fourth spectral exposure	Sample
Fifth spectral exposure	High standard

The plate shall be adjusted for each exposure so that the spectral exposures are in juxtaposition, for ease of comparison with one another.

(*c*) From the finished plates, the lead content shall be estimated on the basis of a visual comparison of the difference in blackness between the lead lines in the spectrum of the sample and in the adjacent standard spectra. Two observers should independently evaluate the plates and the average of the estimations shall be considered as the lead content (Note 7) of the sample.

(*d*) If the iron and cadmium contents of the sample are within the limits set by the high and low standards used for the lead determination, the iron and cadmium may be determined with the same plates from which the lead was determined. If, however, this cannot be done, it will be necessary to repeat the spectrography[1] carried out for the lead determination using standards suitable for the iron and cadmium contents.

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[a] The ten exposures may be recorded on one plate rather than two plates of five exposures each.

Testing for Compliance with Specifications

6. Frequently, the object of the spectrographic inspection is merely to determine whether the lead, iron and cadmium contents are less than certain amounts, as in the case of specification requirements on the composition. For this purpose the analytical procedure described in Sections 2 to 5 may be considerably simplified.

Procedure

7. (*a*) *Standard Solution.*—One standard solution containing the maximum impurity contents allowed by the specifications shall be prepared to a concentration of 0.5 g. of metal per milliliter of hydrochloric acid solution.

(*b*) *Sample Solutions.*—Duplicate solutions of the sample shall be prepared as described in Section 2.

(*c*) *Preparation of Electrodes.*—According to the method described in Section 3, the following electrodes shall be prepared: Four electrodes treated with the standard solution, two electrodes treated with the one sample solution and two electrodes treated with the duplicate sample solution.

(*d*) *Preparation of Spectra.*—Two spectral plates[a] shall be prepared each having four 2-min. exposures (Section 4 (*a*)) in the following order:

First spectral exposure	Standard solution
Second spectral exposure	Sample solution
Third spectral exposure	Sample solution
Fourth spectral exposure	Standard solution

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[a] The eight exposures may be recorded on one plate rather than on two plates of four exposures each.

(*e*) By visual comparison of the blackness of the lead, iron and cadmium lines (Note 6) of the standard spectra with the corresponding lines of the spectra of the samples, a determination may be made as to whether the composition of the sample is within the limits set by the specifications (Note 8).

Explanatory Notes

Note 1: *Acid and Distilled Water.*—The acid and distilled water shall be free from lead, iron and cadmium. The c.p. grade of acid may contain sufficient iron to introduce a significant error in the iron determination. In this event an iron-free acid of sufficient strength may be obtained by distilling the concentrated c.p. grade of hydrochloric acid, the distillate being absorbed in distilled water.

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[1] It is not the intent of this method to limit to three the number of standards whose spectra are recorded on one plate. If it is necessary to use more than three standards for the analysis of one sample, the spectra of more than three may be photographed on one plate. The essential requirements are that the standard spectra be alternated with spectra of the sample and that at least two sample spectra be recorded from each sample solution.

NOTE 2: *Electrodes.*—The electrodes shall be prepared from high-purity graphite rods, $\frac{5}{16}$-in. diameter being recommended (found by test to be free from iron, lead and cadmium). The electrodes which are to contain the sample shall be cut into 2-in. lengths and recessed at one end by drilling an axial hole about 0.15 in. in diameter and 0.25 in. in depth. Prior to use the electrodes shall be burned in a 10-amp. arc for about 2 min., by which treatment any impurities with which the electrodes may have been contaminated in the handling are volatilized.

NOTE 3: *Spectrography.*—The spectrograph shall have quartz optics or a diffraction grating of sufficient resolving power and dispersion to separate clearly the lines of the constituents to be determined from the lines of other elements present in the spectrum of the sample. In illuminating the slit of the spectrograph with the light from the arc, a quartz condensing lens (or lenses) shall be used in such a manner that the images of the electrode tips are sharply defined, one above, the other below, the open portion of the slit, in order to exclude the intense continuous spectrum of the hot carbon electrodes from the spectrograph. Adjustment of the distance between the electrodes shall be made, from time to time, in order to compensate for the burning away of the electrode tips. The same portion of the slit shall be used throughout, preferably the central portion. A moderately slow, fine-grained photographic plate is best suited for this method. Eastman 33 plate is an example of this type of plate. The following developer formula is suggested:

Stock Solution A:	
Water	1000 ml.
Hydroquinone	42 g.
Anhydrous sodium sulfite	85 g.
Potassium bromide	3 g.
Citric acid	1.2 g.

Stock Solution B:	
Water	1000 ml.
Anhydrous sodium carbonate	150 g.

For use take 100 ml. of Solution *A*, 80 ml. of Solution *B* and 420 ml. of water. Develop 4½ min. at 70 F. (21 C.). After development, the plate shall be washed, fixed and dried.

NOTE 4: *Standard Plate.*—A standard plate, on which are recorded the spectra of a series of standard solutions, shall be kept on hand for the purpose of the preliminary estimation (Section 4).

NOTE 5: *Standard Solutions.*—Standard solutions shall be prepared as hydrochloric acid solutions of pure zinc with added lead, iron and cadmium in known ratio to the zinc. A uniform concentration of 0.50 g. of metal per milliliter shall be maintained. The standard solutions shall be prepared as follows:

Solution A (Zinc Stock Solution).—Pure zinc stock solution shall be prepared by dissolving in hydrochloric acid 100 g. of pure zinc, free from iron, lead and cadmium; the volume shall be adjusted to 200 ml.

Solution B (0.1 per cent Lead, 0.1 per cent Iron, 0.1 per cent Cadmium).—99.7 g. of pure zinc, 0.1 g. c.p. lead, 0.1 g. c.p. iron and 0.1 g. c.p. cadmium shall be dissolved in hydrochloric acid. The volume shall be adjusted to 200 ml. This is the starting or high standard solution corresponding to a zinc containing 0.1 per cent each of lead, iron and cadmium. From this solution the next lower standard shall be made by dilution with pure zinc stock solution as follows:

Solution C (0.05 per cent Lead, 0.05 per cent Iron, 0.05 per cent Cadmium).—To 10 ml. of Solution *B* shall be added 10 ml. of Solution *A*. This makes 20 ml. of a standard solution corresponding to a zinc containing 0.05 per cent each of lead, iron and cadmium.

Solution D (0.025 per cent Lead, 0.025 per cent Iron, 0.025 per cent Cadmium).—To 10 ml. of Solution *C* shall be added 10 ml. of Solution *A*. This makes 20 ml. of a standard solution corresponding to a zinc containing 0.025 per cent each of lead, iron and cadmium.

Lower Standards.—The lower standards, 0.013, 0.0063, 0.0031, 0.0016, 0.0008, 0.0004, 0.0002, 0.0001, 0.00005 per cent, shall be made similarly by the process of successive dilutions outlined for Solutions *C* and *D*. The larger volume of Solution *B*, which remains, may be stored in a sealed bottle for the replenishment of the supply of lower standards as required.

The limits of detection and quantitative estimation are approximately 0.0002 per cent for lead, 0.0001 per cent for iron and 0.00005 per cent for cadmium. These limits are those experienced by one laboratory using a large Littrow type spectrograph. They are not invariable, however, and different laboratories will experience different values, depending upon experimental details.

NOTE 6: *Spectral Lines.*—The line used in grading the plate shall not be too dense or black since a very dense line does not show much change in appearance with change in concentration of the corresponding constituent element. The following table lists suitable lines for the estimation of lead, iron and cadmium in high-purity zinc together with an indication of the approximate range of concentration in which the line is useful:

ELEMENTS TO BE DETERMINED	WAVE LENGTHS IN INTERNATIONAL ANGSTROMS OF SUITABLE LINES	RANGE OF CONCENTRATION IN WHICH LINE IS USEFUL, PER CENT
Lead	2873.32 2663.17	0.1 to 0.01
	2833.07	0.1 to 0.0002
Iron	2845.59 2727.54 2714.42	0.1 to 0.05
	2625.68 3021.08 3020.50	0.05 to 0.0001
Cadmium	2980.62	0.1 to 0.05
	3261.05	0.05 to 0.001
	2288.03	0.002 to 0.00005

NOTE 7: *Precision.*—Experience has shown that the precision of determinations by this method is ± 10 per cent of the amount of element being estimated.

NOTE 8: *Reliability of Test.*—Experiment has shown that this method of testing is capable of consistently detecting an off-grade composition if the concentration of lead, iron or cadmium is 20 per cent or more higher than the corresponding concentration in the standard.

TENTATIVE METHOD OF TEST

FOR

QUANTITATIVE SPECTROCHEMICAL ANALYSIS OF ZINC ALLOY DIE CASTINGS FOR MINOR CONSTITUENTS AND IMPURITIES[1]

A.S.T.M. Designation: E 27 - 35 T

This is a **Tentative Standard** and under the Regulations of the Society is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

ISSUED, 1935.[2]

Scope

1. This method[3] refers particularly to the analysis of zinc-base die-casting Alloy Nos. XXI and XXIII, covered by the Tentative Specifications for Zinc-Base Alloy Die Castings (A.S.T.M. Designation: B 86 - 34 T) of the American Society for Testing Materials.[4] The method includes the determination of copper in Alloy No. XXIII and of magnesium, iron, lead, tin and cadmium in Alloys Nos. XXI and XXIII. The determination of nickel in an alloy differing from Alloy No. XXIII by the presence of nickel as a minor constituent is also included. An arc spectrum is used, employing graphite electrodes, one of which is treated with a solution of the sample to be analyzed. Quantitative estimations are made by the comparison of the spectrum of the sample with the spectra of standard samples of known composition.

Preparation of Sample Solution

2. A 20-g. portion of a representative sample of the alloy to be analyzed shall be weighed, placed in a 250-ml. beaker, and dissolved in an equal volume mixture of concentrated hydrochloric and nitric acids. If the volume of the solution is greater than 50 ml., it shall be evaporated to approximately 50 ml., cooled, transferred to a 100-ml. graduate, nitric acid added to bring the volume to 60 ml. and the solution transferred to a small, glass-stoppered bottle. This procedure shall be repeated, thus making available duplicate sample solutions.

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[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the A.S.T.M. Committee E-2 on Spectrographic Analysis.

[2] Accepted for publication as tentative by Committee E-10 on Standards, October 7, 1935.

[3] The procedure is based upon the technique of spectrographic analysis described by C. C. Nitchie, "Quantitative Analysis with the Spectrograph," *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 1, p. 1 (1929).

[4] ***Proceedings***, Am. Soc. Testing Mats., Vol. 34, Part I, p. 706 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 369.

Preparation of Electrode

3. A 0.1 ml. of one of the sample solutions shall be introduced into a recessed graphite electrode (Note 1). Directly after the introduction of the solution, the electrode shall be dried in an oven at 200 F. (93 C.) for about 30 min.

Preliminary Estimation

4. (*a*) The electrode containing the sample solution shall be made the lower and positive member of a pair of electrodes between which an electric arc shall be created by applying a potential of 80 to 100 v. with a direct current of 10 amp. The spectrum of the arc shall be recorded (Note 2) by means of a spectrograph from the moment the arc is struck until the arc has burned for 2 min. The plate thus obtained shall be referred to as the preliminary plate.

(*b*) The preliminary plate shall be compared with a standard plate (Note 3) on which are recorded the spectra of the standard solutions (Note 4). By visual comparison of the blackness of the spectral lines (Note 5) of the constituents and impurities to be determined in the spectrum of the sample with the corresponding lines in the standard spectra, the approximate composition of the sample shall be ascertained.

Final Estimation

5. (*a*) The final estimation of the quantity of each element to be determined shall be made on the basis of plates on each of which are photographed two spectral exposures of the sample and three standard spectral exposures. Beginning with one impurity, for example, lead, three standards of various lead contents, a high, a medium, and a low content, respectively, shall be selected. The medium standard shall be that which is nearest to the lead content of the sample as estimated from the preliminary plate. Six recessed electrodes (Note 1) shall be treated (Section 3) with 0.1-ml. portions each of the standard solutions, preparing two electrodes for each of the three standards. Four electrodes shall be treated with 0.1 ml. each of the sample solutions, preparing two electrodes from the one sample solution and two from the duplicate sample solution. The electrodes shall be dried in an oven at 200 F. (93 C.) for about 30 min.

(*b*) Two spectral plates[a] shall be prepared each having five 2-min. exposures (Section 4 (*a*)) in the following order:

First spectral exposure	Low standard
Second spectral exposure	Sample
Third spectral exposure	Medium standard
Fourth spectral exposure	Sample
Fifth spectral exposure	High standard

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[a] The ten exposures may be recorded on one plate rather than two plates of five exposures each.

The plate shall be adjusted for each exposure so that the spectral exposures are in juxtaposition, for ease of comparison with one another.

(c) From the finished plates the lead content shall be estimated on the basis of a visual comparison of the difference in blackness between the lead spectral lines in the spectrum of the sample and in the adjacent standard spectra. Two observers should independently evaluate the plates and the average of the estimations shall be considered as the lead content (Note 6) of the sample.

(d) If the contents of the other elements to be determined are within the limits set by the high and low standards used for the lead determination, they may be determined with the same plates from which the lead was determined. If, however, this cannot be done, it will be necessary to repeat the spectrography[1] carried out for the lead determination using standards suitable for the contents of the other elements to be determined.

TESTING FOR COMPLIANCE WITH SPECIFICATIONS

6. Frequently, the object of the spectrographic inspection is merely to determine whether the minor constituents are present in the correct amount and the impurities are less than certain amounts, as in the case of specification requirements on the composition. For this purpose the analytical procedure described in Sections 2 to 5 may be considerably simplified. The method of carrying out this test may be described by stating, as an example, the procedure for testing a zinc-base alloy of the A.S.T.M. No. XXIII type for compliance with the Tentative Specifications for Zinc-Base Alloy Die Castings (A.S.T.M. Designation: B 86 – 34 T) of the American Society for Testing Materials.[2]

Procedure

7. (a) *Standard Solutions.*—Two standard solutions shall be prepared each containing the maximum copper, iron, lead, cadmium and tin allowed by the specification, the one containing the minimum amount of magnesium allowed and the other containing the maximum amount of magnesium allowed. These solutions shall be made to a concentration of $\frac{1}{3}$ g. of total metal per milliliter of solution, an equal volume mixture of hydrochloric and nitric acids being used as a solvent. The preparation technique shall be such as to ensure the necessary degree of precision in the nominal composition of the standard solutions.

(b) *Sample Solutions.*—Duplicate sample solutions shall be prepared as described in Section 2.

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[1] It is not the intent of this method to limit to three the number of standards whose spectra are recorded on one plate. If it is necessary to use more than three standards for the analysis of one sample, the spectra of more than three may be photographed on one plate. The essential requirements are that the standard spectra be alternated with spectra of the sample and that at least two sample spectra be recorded from each sample solution.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 706 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 369.

TABLE I.—COMPOSITION OF STANDARD SOLUTIONS FOR A.S.T.M. NO. XXIII TYPE ZINC-BASE DIE-CASTING ALLOY.

Standard Solution	Aluminum, per cent	Magnesium, per cent	Copper, per cent	Iron, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent
Minimum Magnesium........	4.0	0.030	0.10	0.10	0.0070	0.0050	0.0050	remainder
Maximum Magnesium.......	4.0	0.080	0.10	0.10	0.0070	0.0050	0.0050	remainder

(*c*) ***Preparation of Electrodes.***—According to the method described in Section 3, the following electrodes shall be prepared: Two electrodes treated with the minimum magnesium standard solution, two electrodes treated with the maximum magnesium standard solution, two electrodes treated with the one sample solution and two electrodes treated with the duplicate sample solution.

(*d*) ***Preparation of Spectra.***—Two spectral plates[a] shall be prepared each having four 2-min. exposures (Section 4 (*a*)) in the following order:

First spectral exposure....................	Minimum magnesium standard
Second spectral exposure..................	Sample
Third spectral exposure....................	Sample
Fourth spectral exposure..................	Maximum magnesium standard

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[a] The eight exposures may be recorded on one plate rather than on two plates of four exposures each.

(*e*) By visual comparison of the blackness of the appropriate spectral lines in the standard spectra with the corresponding lines of the spectra of the sample, a determination may be made as to whether the composition of the sample is within the limits set by the specifications (Note 4).

EXPLANATORY NOTES

NOTE 1: *Electrodes.*—The electrodes shall be prepared from high-purity graphite rods, $\frac{5}{16}$-in. diameter being recommended (found by test to be free from the elements to be determined in the alloy sample). The electrodes which are to contain the sample shall be cut into 2-in. lengths and recessed at one end by drilling an axial hole about 0.15 in. in diameter and 0.25 in. in depth. Prior to use the electrodes shall be burned in a 10-amp. arc for about 2 min., by which treatment any impurities with which the electrodes may have been contaminated in the handling are volatilized.

NOTE 2: *Spectrography.*—The spectrograph shall have quartz optics or a diffraction grating of sufficient resolving power and dispersion to separate clearly the lines of the constituents to be determined from the lines of other elements present in the spectrum of the sample. In illuminating the slit of the spectrograph with the light from the arc, a quartz condensing lens (or lenses) shall be used in such a manner that the images of the electrode tips are sharply defined, one above, the other below, the open portion of the slit, in order to exclude the intense continuous spectrum of the hot carbon electrodes from the spectrograph. Adjustment of the distance between the electrodes shall be made, from time to time, in order to compensate for the burning away of the electrode tips. The same portion of the slit shall be used throughout, preferably the central portion. A moderately slow, fine-grained photographic plate is best suited for this method. Eastman 33 plate is an example of this type of plate. The following developer formula is suggested:

Stock Solution A:

Water	1000 ml.
Hydroquinone	42 g.
Anhydrous sodium sulfite	85 g.
Potassium bromide	3 g.
Citric acid	1.2 g.

Stock Solution B:

Water	1000 ml.
Anhydrous sodium carbonate	150 g.

For use take 100 ml. of Solution *A*, 80 ml. of Solution *B* and 420 ml. of water. Develop 4½ min. at 70 F. (21 C.) After development, the plate shall be washed, fixed and dried.

NOTE 3: *Standard Plate.*—A standard plate, on which are recorded the spectra of a series of standard solutions, shall be kept on hand for the purpose of the preliminary estimation (Section 4).

NOTE 4: *Standard Solutions.*—Standard solutions shall be prepared as acid solutions of the major alloying constituents with added amounts of the metals to be determined in known ratio to the total weight of metal. The acid used shall be an equal volume mixture of concentrated hydrochloric and nitric acids. A uniform concentration of ⅓ g. of total metal per milliliter shall be maintained.

The major alloying constituents, zinc, aluminum and copper, shall be present in the standards in approximately the same proportions as they exist in the alloy for the analysis of which the standards are prepared. For example, standards for the analysis of A.S.T.M. No. XXI zinc-base die casting alloy shall contain 4 per cent aluminum and 3 per cent copper, the metals to be determined, and the balance as zinc. A separate set of standards shall be required for the analysis of A.S.T.M. No. XXIII zinc-base alloy. The latter standards shall not contain the major constituent, 3 per cent copper.

For each type of alloy a separate set of standards shall be required, differing from one another as noted in the previous paragraph. The members of each set will differ from one another in the concentrations of the elements to be determined. The concentrations of the several elements shall be varied from the highest standard to the succeeding lower standards in a geometric progression of ratio 1:2.

The following example will illustrate the method of preparing a set of standard solutions. This set is designed for the determination of magnesium, nickel, copper, iron, lead, cadmium and tin in an alloy of the A.S.T.M. No. XXIII type:

COMPOSITION OF STANDARD SOLUTIONS FOR THE ANALYSIS OF A.S.T.M. NO. XXIII TYPE ZINC-BASE DIE CASTING ALLOY

Standard Solutions	Aluminum, per cent	Magnesium, per cent	Nickel, per cent	Copper, per cent	Iron, per cent	Lead, per cent	Cadmium, per cent	Tin, per cent	Zinc, per cent
A	4.0	0.20	0.20	0.20	0.20	0.040	0.020	0.020	remainder
B	4.0	0.10	0.10	0.10	0.10	0.020	0.010	0.010	remainder
C	4.0	0.050	0.050	0.050	0.050	0.010	0.0050	0.0050	remainder
D	4.0	0.025	0.025	0.025	0.025	0.0050	0.0025	0.0025	remainder
E	4.0	0.013	0.013	0.013	0.013	0.0025	0.0013	0.0013	remainder
F	4.0	0.0063	0.0063	0.0063	0.0063	0.0013	0.00063	0.00063	remainder

Pure Alloy Base Solution.—4 g. of pure aluminum[1] and 96 g. of pure zinc[1] shall be dissolved in an equal volume mixture of hydrochloric and nitric acids. The volume of the solution shall be adjusted to 300 ml.

Basic Standard Solution.—46.24 g. of pure zinc[1], 2.00 g. of pure aluminum[1], 0.40 g. of magnesium, 0.40 g. of nickel, 0.40 g. of copper, 0.40 g. of iron, 0.080 g. of lead and 0.040 g. of cadmium shall be dissolved in an equal volume mixture of hydrochloric and nitric acids. 0.040 g. of tin shall be dissolved in a small volume of cold hydrochloric acid and added to the solution of the other metals. The volume of the final solution shall be adjusted to 150 ml. This solution corresponds to an alloy containing 4.0 per cent aluminum, 0.8 per cent each of magnesium, nickel, copper and iron, 0.16 per cent lead, 0.08 per cent each of cadmium and tin, and the remainder of zinc.

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[1] The aluminum and zinc must be sufficiently free from magnesium, nickel, copper, iron, lead, cadmium and tin so as not to significantly alter the intended or nominal composition of the standard solutions.

Standard Solution A.—To 10 ml. of the Basic Standard Solution shall be added 30 ml. of the Pure Alloy Base Solution. This makes 40 ml. of Standard Solution *A* of the composition given in the above table.

Standard Solution B.—To 10 ml. of Standard Solution *A* shall be added 10 ml. of the Pure Alloy Base Solution. This makes 20 ml. of Standard Solution *B* of the composition given in the above table.

Standard Solution C.—To 10 ml. of Standard Solution *B* shall be added 10 ml. of the Pure Alloy Base Solution. This makes 20 ml. of Standard Solution *C* of the composition given in the above table.

Lower Standards.—The lower Standard Solutions *D*, *E* and *F* shall be made similarly by the process of successive dilutions outlined for Solutions *B* and *C*.

The quantity of the Pure Alloy Base Solution and the Basic Standard Solution which remain may be stored in sealed bottles for the replenishment of the supply of standards as required.

Alternative Standard Solutions.—It is not the intent of this method to require that standard solutions be made with the elements to be determined in the concentrations set forth above. Some other ratio of the concentrations of the several elements in any one standard may prove more convenient. The particular scheme outlined above is designed to permit the estimation of a number of elements on one plate using the same three standard spectral exposures for each estimation. Thus, a large proportion of samples of this type alloy can be analyzed with Standard Solutions *C*, *D* and *E* alone.

It may also prove convenient in some laboratories to limit the number of metals in any one set of standards to a fewer number than those listed above. For example, one may wish to have merely magnesium, lead and tin in the standard solution in addition, of course, to the aluminum and zinc.

NOTE 5: *Spectral Lines.*—The lines used in grading the plate shall not be too dense or black since a very dense line does not show much change in appearance with change in concentration of the corresponding element. The following table lists suitable lines for the estimation of magnesium, nickel, copper, iron, lead, cadmium and tin in zinc alloy die castings together with an indication of the approximate range of concentration in which the line is useful:

ELEMENTS TO BE DETERMINED	WAVE LENGTHS IN INTERNATIONAL ANGSTROMS OF SUITABLE LINES	RANGE OF CONCENTRATION IN WHICH LINE IS USEFUL, PER CENT
Magnesium	2782.99 2781.43 2779.85 2778.29 2776.71	0.25 to 0.004
Nickel	3031.87 2821.30	1.0 to 0.1
	3057.65 3054.32	0.1 to 0.008
	3012.01 3003.63	0.1 to 0.004
Copper	2961.18 2824.38 2618.38	1.0 to 0.03
	3273.96 3247.55	0.03 to 0.0005

ELEMENTS TO BE DETERMINED	WAVE LENGTHS IN INTERNATIONAL ANGSTROMS OF SUITABLE LINES	RANGE OF CONCENTRATION IN WHICH LINE IS USEFUL, PER CENT
Iron	2929.01	1.0 to 0.05
	2912.16	
	2788.11	0.2 to 0.01
	2723.58	
	2720.91	0.1 to 0.008
	2719.04	0.1 to 0.002
	3020.64	0.02 to 0.0005
	3020.50	
Lead	2614.20	0.1 to 0.001
	2833.07	0.02 to 0.0004
Cadmium	3261.05	0.1 to 0.001
	2288.03	0.001 to 0.00005
Tin	2863.32	0.05 to 0.002
	2839.99	

NOTE 6: *Precision.*—Experience has shown that the precision of determinations by this method is ± 10 per cent of the amount of element being estimated.

NOTE 7: *Reliability of Test.*—Experiment has shown that this method of testing is capable of consistently detecting an off-grade composition if the concentrations of the elements to be determined differ by 20 per cent or more from the corresponding concentrations in the standard.

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative revisions of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticisms, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS

Tentative Revision[1] of Standard Specifications for Open-Hearth Carbon-Steel Rails (A.S.T.M. Designation: A 1 - 30):[2]

Section 3.—Change the table of chemical requirements, appearing in this section, to read as follows by the addition of the italicized figures and the omission of those in brackets:

Elements Considered	Weight, lb. per yd.				
	50-69	70-84	85-100	101-120	121-140
Carbon, per cent.....	0.50-0.63	0.53-0.70	[0.62] *0.64*-0.77	0.67-[0.83] *0.80*	[0.72-0.89] *0.69-0.82*
Manganese, per cent..	0.60-0.90	0.60-0.90	0.60-0.90	[0.50-0.90] *0.70-1.00*	[0.50-0.90] *0.70-1.00*
Phosphorus, max., per cent...........	0.04	0.04	0.04	0.04	0.04
Silicon, min., per cent.	[0.15] *0.10-0.23*	[0.15] *0.10-0.23*	[0.15] *0.10-0.23*	[0.15] *0.10-0.23*	[0.15] *0.10-0.23*

Revision submitted, June, 1934.

Section 4 (b).—Add the following sentences at the end of this paragraph:

The "O" position, as shown in Fig. 1, is located at a point one-third of the distance from the upper corner to the center of the head of the rail. The "M" position, also shown in Fig. 1, is the intersection of the vertical axis of the section and the line joining the upper tangent point of the fillets under the head.

Revision submitted, June, 1935.

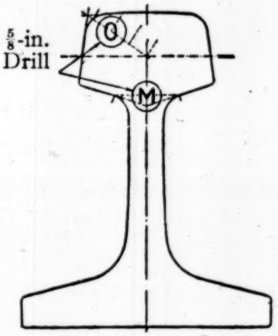

FIG. 1.—Location of "O" and "M" Positions for Obtaining Samples for Chemical Analysis.

Figure 1.—Add the accompanying Fig. 1 which shows the location of the "O" and "M" positions for obtaining samples for chemical analysis.

Revision submitted, June, 1935.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

Section 6.—Change Paragraph (*a*) from its present form: namely,

6. (*a*) Ductility and resistance to impact will be determined by the standard A.R.E.A. drop testing machine, with test specimens from 4 ft. to 6 ft. long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. These specimens shall be marked on the base with gage marks 1 in. apart for 3 in. each side of the center of the test specimens for measuring the ductility of the metal. The distance between supports shall be 3 ft. for sections under 106 lb. For sections 106 lb. and over it shall be 4 ft.

to read as follows:

6. (*a*) The drop testing machine shall be the standard of the American Railway Engineering Association.

(*b*) The tup shall weigh 2000 lb., and have a striking face with a radius of 5 in.

(*c*) The anvil block shall weigh 20,000 lb., and be supported on springs.

(*d*) The supports for the test specimens shall be a part of, or firmly secured to, the anvil. These supports shall be spaced 3 ft. between centers for rails 100 lb. per yd. or less in weight and 4 ft. for rails over 100 lb. per yd. in weight. The bearing surfaces of the supports shall have a radius of 5 in.

Transfer Paragraph (*b*) of this section to appear as Paragraph (*b*) of a new Section 7.

Revision submitted, June, 1935.

New Section.—Add the following Paragraph (*a*) to a new Section 7, renumbering the remaining sections accordingly. With the inclusion of Paragraph (*b*) from Section 6 this new section will read as follows:

7. (*a*) Drop tests shall be made on test specimens of rail not less than 4 ft. and not more than 6 ft. in length. These test specimens shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks 1 in. apart for 3 in. each side of the center of the test specimens for measuring the ductility of the metal.

(*b*) The temperature of the test specimens shall not exceed 38 C. (100 F.).

Revision submitted, June, 1935.

Section 12.—Change this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

12. The section of the rails shall conform as accurately as possible to the templates ***or drawings*** furnished by the purchaser. A variation of $\frac{1}{64}$ in. less and $\frac{1}{32}$ in. greater than the specified height will be permitted. A variation of $\frac{1}{16}$ in. in the [length] ***width*** of either flange will be permitted, but the variation in total width of base must not exceed $\frac{1}{16}$ in. No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing template approved by the purchaser may stand out not to exceed $\frac{1}{16}$ in. laterally.

Revision submitted, June, 1934.

Section 18.—Add to the first sentence of Paragraph (*b*) a reference to the A.R.E.A. type rails, thus making the opening phrase read: "Rails of A.R.A. or A.R.E.A. type of sections."

Add the following as a new Paragraph (*c*):

(*c*) Rails that are not hot stamped.

Revision submitted, June, 1934.

Section 19.—Change this section from its present form to read as follows:

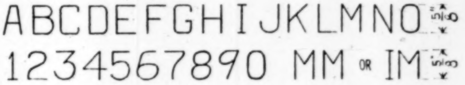
(*a*) The data and order of arrangement of the branding shall be as shown in the following typical branding, the design of letters and numerals to be optional with the manufacturer:

11025	R.E.	O.H.	DOE	1930	IIIIII
(Weight and Section Number)	(Type)	(Kind of Steel)	(Manufacturer and Mill)	(Year Rolled)	(Month Rolled)

(*b*) The heat number and the ingot number as rolled shall be stamped in the web of each rail where it will not be covered by the joint bars. The data used in stamping and arrangement thereof shall be as shown in the following typical stamping:

Example 1:	63345	E	17
	(Heat Number)	(Rail Letter)	(Ingot No.)
Example 2:	49021	A	5

(*c*) The top rails shall normally be lettered "A," and succeeding ones "B," "C," "D," "E," etc., consecutively, but in case top discard is greater than normal, the rail lettering shall conform to the amount of discard, the top rail becoming "B," or other succeeding letter to suit the condition. Design and size of letters and numerals to be used in stamping shall be as here shown:



(*d*) Only the "A," "B" and "C" rails are required to be lettered when the normal weight per yard is less than 70 lb. Revision submitted, June, 1934.

Section 20 (*e*).—Change from its present form: namely,

(*e*) All rails of heats the carbon content of which exceeds the mean carbon percentage of the specific range shall have both ends painted blue.

Individual rails shall be painted only one color, according to the order of precedence listed above.

to read as follows:

(*e*) All rails of a heat whose carbon content is in the upper five points of the carbon percentage of the specified range shall have both ends painted blue.

Individual rails shall be painted only one color, according to the order of precedence listed above. Revision submitted, June, 1934.

Section 23 (*c*).—Change to read as follows by the addition of the italicized words:

(*c*) Rails accepted will be paid for according to actual weights, ***subject to the limitations of Section 13.*** Revision submitted, June, 1934.

Tentative Revision[1] of Standard Specifications for Quenched High-Carbon-Steel Splice Bars (A.S.T.M. Designation: A 49 – 21):[2]

Section 3.—Change the table of requirements as to chemical composition from its present form: namely,

Carbon	not over 0.60 per cent
Manganese	not over 0.80 per cent
Phosphorus	not over 0.04 per cent

to read as follows:

Carbon, per cent	0.35 to 0.60
Manganese, max., per cent	0.80
Phosphorus, max., per cent	0.04

Revision submitted, June, 1935.

Section 4.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. [This] *The* analysis shall be made from drillings taken at least $\frac{1}{8}$ in. beneath the surface of a test ingot obtained during the pouring of [the] *each* melt. The chemical composition thus determined shall be reported to the purchaser or his representative and [the percentages of carbon, manganese and phosphorus] shall conform to the requirements specified in Section 3.

Revision submitted, June, 1935.

Section 5.—Change from its present form: namely,

5. An analysis may be made by the purchaser from a finished splice bar representing each melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

to read as follows:

5. An analysis may be made by the purchaser from a finished bar representing each melt. The percentages of carbon and manganese thus determined shall conform to the requirements specified in Section 3 and the phosphorus content shall not exceed that specified by more than 25 per cent.

Revision submitted, June, 1935.

Section 6 (a).—Change from its present form: namely,

6. (*a*) The splice bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100 000
Yield point, lb. per sq. in.	65 000
Elongation in 2 in., per cent	10

to read as follows:

6. (*a*) The joint bars shall conform to the following minimum requirements as to tensile properties:

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

Tensile strength, lb. per sq. in.	100 000
Yield point, lb. per sq. in.	70 000
Elongation in 2 in., per cent but in no case less than 12 per cent.	$\frac{1\,600\,000}{\text{tens. str.}}$
Reduction of area, per cent but in no case less than 25 per cent.	$\frac{3\,500\,000}{\text{tens. str.}}$

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Quenched Carbon-Steel Track Bolts (A.S.T.M. Designation: A 50 – 33);[2]

Tentative Revision[1] of Standard Specifications for Quenched Alloy-Steel Track Bolts (A.S.T.M. Designation: A 51 – 33):[2]

The Tentative Specifications for Heat-Treated Carbon- and Alloy-Steel Track Bolts (A 183 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications A 50 – 33 and A 51 – 33.

Tentative Revision[1] of Standard Specifications for Carbon-Steel Car and Tender Axles (A.S.T.M. Designation: A 21 – 27):[2]

Section 1.—Change this section to read as follows by the addition of the italicized words and the omission of the word in brackets:

1. These specifications cover tapered axles up to and including those 6½ in. in nominal diameter at the center. Axles over 6½ in. in ***nominal*** diameter at the center ***which*** shall be annealed, [and] shall be in accordance with the Tentative Specifications for Carbon-Steel Forgings for Locomotives (A.S.T.M. Designation: A 20 – 31 T) of the American Society for Testing Materials.[4]

Note.—Add the following Note to Section 1:

NOTE.—Axles with parallel sides, either untreated or annealed as specified, shall be in accordance with the Tentative Specifications for Carbon-Steel Forgings for Locomotives (A.S.T.M. Designation: A 20 – 31 T) of the American Society for Testing Materials.[4]

Revision submitted, June, 1934.

Section 3.—In the table of chemical requirements change the present range in manganese content from "0.40 to 0.70 per cent" to read "0.40 to 0.90 per cent."

Revision submitted, June, 1934.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] See p. 556.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 662 (1931); also 1935 Book of A.S.T.M. Tentative Standards, p. 55.

Section 8.—Add the following paragraph as Paragraph (*b*), lettering the present section as Paragraph (*a*):

(*b*) When less than 15 tons of any one design are ordered, the manufacturer shall have the option of making axles from a previously tested melt and furnishing copy of such test, or of making a tension test to the requirements for untreated forgings as specified in the Tentative Specifications for Carbon-Steel Forgings for Locomotives (A.S.T.M. Designation: A 20 - 31 T) of the American Society for Testing Materials.[1]

Revision submitted, June, 1934.

Section 9.—Change this section from its present form: namely,

9. (*a*) All axles shall be made and finished in a workmanlike manner and shall conform to the sizes and shapes specified by the customer and all journals and wheel seats shall be rough turned. In centering, unless otherwise specified, 60-deg. centers shall be used, with large diameter of counter-sink not less than ⅞ in. and with clearance drilled ½ in. deep.

(*b*) Unless otherwise specified, axles shall be smooth forged, except the wheel seats and journals, which shall be rough turned.

to read as follows:

9. The axles shall conform to the sizes and shapes specified by the purchaser. Unless otherwise specified, axles shall have smooth-forged finish except on wheel seats and journals, which shall be rough turned. Centering shall be 60 deg. with clearance drilled for points.

Revision submitted, June, 1934.

Tentative Revision[2] of Standard Specifications for Quenched-and-Tempered Carbon-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars (A.S.T.M. Designation: A 19 - 27):[3]

Section 5.—Change from its present form: namely,

5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

to read as follows:

5. (*a*) Unless otherwise specified by the purchaser, all axles, shafts and similar forgings having a minimum diameter over 7 in. shall be bored. The boring shall be done before quenching.

(*b*) In the case of boring, the diameter of the hole, unless otherwise specified, shall be at least 20 per cent of the maximum outside diameter of the forging, exclusive of collars and flanges.

Revision submitted, June, 1931.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 662 (1931); also 1935 Book of A.S.T.M Tentative Standards, p. 55.

[2] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[3] 1933 Book of A.S.T.M. Standards, Part I.

Tentative Revision[1] of Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars (A.S.T.M. Designation: A 63 - 27):[2]

Section 5.—Make the same change in this section as recommended in Section 5 of Specifications A 19 - 27 above.

Revision submitted, June, 1931.

Tentative Revision[1] of Standard Specifications for Wrought Solid Carbon-Steel Wheels for Electric Railway Service (A.S.T.M. Designation: A 25 - 24):[2]

Section 3.—Separate composition for acid steel is to be eliminated and the same chemistry used for both acid and basic steel. It is accordingly recommended that the table of chemical requirements appearing in this section be changed from its present form: namely,

	ACID	BASIC
Carbon, per cent	0.60 - 0.80	0.65 - 0.85
Manganese, per cent	0.55 - 0.80	0.55 - 0.80
Phosphorus, per cent	not over 0.05	not over 0.05
Sulfur, per cent	not over 0.05	not over 0.05
Silicon, per cent	0.15 - 0.35	0.10 - 0.30

to read as follows:

Carbon, per cent	0.65 to 0.85
Manganese, per cent	0.60 to 0.85
Phosphorus, max., per cent	0.05
Sulfur, max., per cent	0.05
Silicon, min., per cent	0.15

Revision submitted, June, 1934.

Section 5.—Change this section from its present form: namely,

5. An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

to read as follows:

5. An analysis may be made by the purchaser from a wheel block or from a finished wheel selected by his representative from each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Samples from wheel blocks shall be drilled from the end of the block at any point midway between the center and outside. The finished wheels may be sampled by taking drillings direct from the plate, or from the slug

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

hot-punched or cored out of the plate; taken so that it does not impair the usefulness of the wheel. Samples shall be taken by drilling entirely through the plate or slug. Drillings from any one block or wheel shall be thoroughly mixed together and they shall be clean and free from scale, oil and other foreign substances.

Revision submitted, June, 1934.

Section 7.—The present permissible variations are intended for wheels operating on T-rails. It is now proposed to include variations for wheels operating on grooved rails which will be one-half of the existing tolerances. It is accordingly recommended that Paragraphs (*a*), (*b*), (*c*), and (*j*) be changed to read as follows by the addition of the italicized words and figures:

(*a*) Height of Flange.—The height of flange shall not vary from that specified by more than $\pm\frac{1}{16}$ in. *for wheels operating on T-rails, nor more than* $\pm\frac{1}{32}$ *in. for wheels operating on grooved rails.*

(*b*) Thickness of Flange.—The thickness of flange shall not vary from that specified by more than $\pm\frac{1}{16}$ in. *for wheels operating on T-rails, nor more than* $\pm\frac{1}{32}$ *in. for wheels operating on grooved rails.*

(*c*) Radius of Throat.—The radius of throat shall not vary from that specified by more than $\pm\frac{1}{16}$ in. *for wheels operating on T-rails, nor more than* $\pm\frac{1}{32}$ *in. for wheels operating on grooved rails.*

(*j*) Limit-of-Wear Groove.—When a limit-of-wear groove is specified, its location shall not vary from that specified by more than $\pm\frac{1}{16}$ in. *for wheels operating on T-rails, nor more than* $\pm\frac{1}{32}$ *in. for wheels operating on grooved rails.*

It is also recommended that Paragraphs (*g*) and (*h*) which read as follows be deleted from this section:

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

Table I.—Change Table I in accordance with the modifications being made in Section 7 (*a*), (*b*), (*c*), (*g*), (*h*), and (*j*).

Revision submitted, June, 1934.

Tentative Revision[1] of Standard Specifications for Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A.S.T.M. Designation: A 68-27):[2]

Section 1.—Change to read as follows by the omission of the words in brackets:

1. These specifications cover [two grades of] carbon-steel bars [with special silicon requirements] to be used for the manufacture of railway springs. [determined by the carbon ranges specified in Section 3. The choice of the grade of bar to be used for the manufacture of any spring will depend on the design of the spring and the stresses and service for which it is intended. The purposes for which these grades

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

are frequently used are as follows: Grade A, for elliptical and helical springs; Grade B, for helical springs.]

Revision submitted, June, 1935.

Section 3.—Change the table of requirements as to chemical composition from its present form: namely,

ELEMENTS CONSIDERED	GRADE A	GRADE B
Carbon, per cent	0.90 – 1.10	0.95 – 1.15
Manganese, max., per cent	0.50	0.50
Phosphorus, max., per cent	0.05	0.05
Sulfur, max., per cent	0.05	0.05
Silicon, per cent	0.25 – 0.50	0.25 – 0.50

to read as follows:

Carbon, per cent	0.90 to 1.05
Manganese, per cent	0.25 to 0.50
Phosphorus, max., per cent	0.05
Sulfur, max., per cent	0.05
Silicon, min., per cent	0.15

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Boiler Rivet Steel and Rivets (A.S.T.M. Designation: A 31 – 24):[2]

Section 2.—In the table of chemical requirements change the present requirement for sulfur from "not over 0.045 per cent" to read "not over 0.05 per cent."

Revision submitted, June, 1934.

Tentative Revision[1] of Standard Specifications for Structural Rivet Steel (A.S.T.M. Designation: A 141 – 33):[2]

Section 2.—Make the same change in this section as recommended in Section 2 of Specifications A 31 – 24 above.

Revision submitted, June, 1934.

Tentative Revision[1] of Standard Specifications for Steel for Bridges (A.S.T.M. Designation: A 7 – 34):[2]

Section 13.—Add the following paragraph as Paragraph (*b*), lettering the present section as Paragraph (*a*):

(*b*) Surface imperfections that do not affect the full utility of the pieces, shall not be considered as injurious defects in structural shapes, $\frac{3}{8}$ in. or more in thickness. Such pieces may be processed by the following methods in order to give them a workmanlike finish:

(*1*) When the surface imperfections are less than $\frac{1}{16}$ in. in depth, they may be removed by grinding.

(*2*) When the surface imperfections are $\frac{1}{16}$ in. or more in depth, the pieces may be subjected to chipping and welding under limiting conditions as follows:

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

The cross-sectional area of any piece shall not be reduced more than 1.5 per cent at any point, nor shall the total area of the chipped surface of any piece exceed 2 per cent of the total surface area of that piece.

After any imperfection has been completely removed, the maximum depth of depression shall not exceed the following:

THICKNESS OF MATERIAL, IN.	DEPTH OF DEPRESSION, MAX., IN.
$\frac{3}{8}$ up to $\frac{1}{2}$	$\frac{1}{16}$
$\frac{1}{2}$ up to 1	$\frac{1}{8}$
1 up to $1\frac{1}{4}$	$\frac{3}{16}$
$1\frac{1}{4}$ up to $2\frac{1}{4}$	$\frac{1}{4}$
$2\frac{1}{4}$ up to $3\frac{1}{2}$	$\frac{3}{8}$

The chipping and welding shall be performed under constant control by the manufacturer. All welding shall be done by qualified welders using suitable coated welding rods. The welds shall be sound; the weld metal being thoroughly fused on all surfaces and edges without undercutting or overlap. Weld metal shall project at least $\frac{1}{16}$ in. above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding to make it flush with the rolled surface and produce a workmanlike finish.

Revision submitted, August, 1935.

Tentative Revision[1] of Standard Specifications for Steel for Buildings (A.S.T.M. Designation: A 9 – 34):[2]

Section 13.—Make the same change in this section as recommended in Section 13 of Specifications A 7 – 34, above. Revision submitted, August, 1935.

Tentative Revision[1] of Standard Specifications for Structural Silicon Steel (A.S.T.M. Designation: A 94 – 33):[3]

Section 14.—Make the same change in this section as recommended in Section 13 of Specifications A 7 – 34, above. Revision submitted, August, 1935.

Tentative Revision[1] of Standard Specifications for Structural Steel for Ships (A.S.T.M. Designation: A 131 – 33):[2]

Section 2.—In the table of chemical requirements change the present sulfur requirement for structural steel and steel for cold bending from "not over 0.06 per cent" to read "not over 0.05 per cent." Revision submitted, August, 1934.

Also change the present sulfur requirement for rivet steel from "not over 0.045 per cent" to read "not over 0.05 per cent."

Revision submitted, June, 1934.

Section 5.—Change this section by the addition of the following clause as a new Paragraph (*b*), relettering the present Paragraph (*b*) as Paragraph (*c*):

(*b*) Flat rolled steel $\frac{3}{16}$ in. and under in thickness, shapes less than 1 sq. in. in cross-section, and bars, other than flats, less than $\frac{1}{2}$ in. in thickness or diameter, shall not be subjected to tension tests.

Revision submitted, June, 1934.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1934 Supplement to Book of A.S.T.M. Standards.

[3] 1933 Book of A.S.T.M. Standards, Part I.

Section 6 (a).—Change this paragraph to provide a minimum elongation in 8 in. of 18 per cent for thicknesses over $\frac{3}{4}$ in. by the addition of the italicized words and figures and by the omission of those in brackets:

> 6. (*a*) For material over $\frac{3}{4}$ in. in thickness or diameter, a deduction from the percentage of elongation in 8 in. specified in Section 5 (*a*) of 0.25 per cent, shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness or diameter above $\frac{3}{4}$ in. to a minimum of [16] *18* per cent for *both* the structural [grade and 18 per cent for] *and* the rivet steel and cold bending grades.

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A.S.T.M. Designation: A 107 – 33):[2]

Section 5. (*a*).—Change from its present form: namely,

> 5. (*a*) For bessemer steel a carbon determination shall be made of each melt; and determinations for manganese, phosphorus and sulfur, representing the average of the melts made in each twelve-hour period.

to read as follows:

> 5. (*a*) For bessemer steel an analysis of each melt shall be made for carbon and manganese; and determinations for phosphorus representing the average of melts made during each 8-hr. turn. For bessemer free-cutting steels the sulfur shall be determined for each melt.

Revision submitted, June, 1935.

Section 6 (a).—Change this section to read as follows by the addition of the italicized words and figures:

> 6. (*a*) Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt or lot of bars, of bessemer steel. The average chemical composition thus determined shall not vary from the limits specified more than 0.03 per cent over [or] *and* 0.02 per cent under in carbon *for ranges up to 0.80 per cent maximum, or more than 0.04 per cent over and 0.03 per cent under for carbon ranges higher than 0.90 per cent maximum;* 0.03 per cent over [or] *and* 0.02 per cent under in manganese; 0.005 per cent over in phosphorus; and (*except on the free-cutting steel grades*) 0.005 per cent over in sulfur.

Revision submitted, June, 1935.

Table I.—Change the table of chemical compositions of open-hearth, bessemer and screw-steel grades from its present form to read as shown in the accompanying Table I.

Revision submitted, June, 1935.

Table II.—Change the tabulated requirements for "Flats, Square-Edge and Round-Edge" shown in the present Table II by deleting the column for flats $\frac{3}{16}$ in. in thickness or under, and by changing the heading over the next column from "Over $\frac{3}{16}$ to $\frac{1}{2}$, incl." to read "$\frac{1}{4}$ to $\frac{1}{2}$, incl."

Revision submitted, June, 1935.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

TABLE I.—GRADES AND CHEMICAL COMPOSITIONS.

(Revised Table I for both Specifications A 107 and A 108, with the exception as noted in Footnote 1)

Grades	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent
OPEN-HEARTH GRADES				
Grade Designations to be Supplied	0.12 max.	0.55 max.	0.045 max.	0.055 max.
	0.05 to 0.15	0.30 to 0.60	0.045 max.	0.055 max.
	0.10 to 0.20	0.30 to 0.60	0.045 max.	0.055 max.
	0.10 to 0.20	0.70 to 1.00	0.045 max.	0.055 max.
	0.15 to 0.25	0.30 to 0.60	0.045 max.	0.055 max.
	0.15 to 0.25	0.70 to 1.00	0.045 max.	0.055 max.
	0.20 to 0.30	0.30 to 0.60	0.045 max.	0.055 max.
	0.20 to 0.30	0.70 to 1.00	0.045 max.	0.055 max.
	0.25 to 0.35	0.60 to 0.90	0.045 max.	0.055 max.
	0.30 to 0.40	0.60 to 0.90	0.045 max.	0.055 max.
	0.35 to 0.45	0.60 to 0.90	0.045 max.	0.055 max.
	0.35 to 0.45	0.40 to 0.70	0.045 max.	0.055 max.
	0.40 to 0.50	0.60 to 0.90	0.045 max.	0.055 max.
	0.40 to 0.50	0.40 to 0.70	0.045 max.	0.055 max.
	0.45 to 0.55	0.60 to 0.90	0.045 max.	0.055 max.
	0.45 to 0.55	0.40 to 0.70	0.045 max.	0.055 max.
	0.50 to 0.60	0.60 to 0.90	0.04 max.	0.055 max.
	0.50 to 0.60	0.90 to 1.20	0.04 max.	0.055 max.
	0.55 to 0.70	0.60 to 0.90	0.04 max.	0.055 max.
	0.60 to 0.75	0.60 to 0.90	0.04 max.	0.055 max.
	0.60 to 0.75	0.90 to 1.20	0.04 max.	0.055 max.
	0.65 to 0.80	0.60 to 0.90	0.04 max.	0.055 max.
	0.70 to 0.85	0.60 to 0.90	0.04 max.	0.055 max.
	0.75 to 0.90	0.60 to 0.90	0.04 max.	0.055 max.
	0.80 to 0.95	0.60 to 0.90	0.04 max.	0.055 max.
	0.85 to 1.00	0.60 to 0.90	0.04 max.	0.055 max.
	0.90 to 1.05	0.25 to 0.50	0.04 max.	0.055 max.
BESSEMER GRADES[1]				
Bessemer welding	0.12 max.	0.60 max.	0.11 max.	0.08 max.
Bessemer soft	0.15 max.	0.70 max.	0.11 max.	....
Bessemer 15 to 25 carbon	0.15 to 0.25	0.90 max.	0.11 max.	....
Bessemer 25 to 35 carbon	0.25 to 0.35	0.90 max.	0.11 max.	....
Bessemer 35 to 50 carbon	0.35 to 0.50	0.90 max.	0.11 max.	....
FREE-CUTTING STEEL GRADES				
Grade Designations to be Supplied	0.08 to 0.16	0.60 to 0.90	0.09 to 0.13	0.10 to 0.20
	0.08 to 0.16	0.60 to 0.90	0.09 to 0.13	0.20 to 0.30
	0.10 to 0.20	0.70 to 1.00	0.045 max.	0.075 to 0.15
	0.15 to 0.25	0.60 to 0.90	0.045 max.	0.075 to 0.15
	0.10 to 0.20	1.00 to 1.30	0.045 max.	0.075 to 0.15
	0.10 to 0.20	1.30 to 1.60	0.045 max.	0.075 to 0.15
	0.25 to 0.35	1.35 to 1.65	0.045 max.	0.075 to 0.15
	0.30 to 0.40	1.35 to 1.65	0.045 max.	0.075 to 0.15
	0.35 to 0.45	1.35 to 1.65	0.045 max.	0.075 to 0.15

[1] These bessemer grades, which are the same as the existing requirements, apply only to Table I, appearing in Specifications A 107. There is no change from the present requirements for the bessemer grade in Specifications A 108 which read as follows: "Bessemer Soft, carbon, 0.15 max.; manganese, 0.60 max.; and phosphorus, 0.11 max."

Tentative Revision[1] of Standard Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A.S.T.M. Designation: A 108 – 33):[2]

Section 1 (a).—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

1. (*a*) These specifications cover commercial cold-finished bar steels of grades considered to be in common use, including cold-finished [bessemer screw stock and cold-finished open-hearth screw stock] *free-cutting steels*, also cold-finished shafting and commercial key stock.

Revision submitted, June, 1935.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

Section 2 (c).—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

(*c*) The steel in [bessemer and open-hearth screw stock] ***the free-cutting steels*** shall be [free-cutting and] suitable for high-speed screw machine work, leaving a smooth finish after machining under proper conditions.

Revision submitted, June, 1935.

Table I.—Change the chemical compositions of the open-hearth grades and the screw-steel grades in this table to conform to those for the open-hearth grades and free-cutting steel grades shown in the accompanying Table I. The title and present requirements for the bessemer grade are to be retained without change.

Revision submitted, June, 1935.

Table II.—Change this table from its present form to read as follows:

TABLE II.—VARIATIONS IN RANGES AND IN MAXIMUM LIMITS SPECIFIED IN TABLE I PERMITTED ON CHECK ANALYSIS

Elements considered	Permissible Variations from Maximum Limit, per cent	
	Under	Over
Carbon, max. limits up to 0.25 per cent, incl	0.02	0.03
Carbon, max. limits over 0.25 to 0.40 per cent, incl	0.03	0.04
Carbon, max. limits over 0.40 to 0.60 per cent, incl	0.03	0.05
Carbon, max. limits over 0.60 to 0.80 per cent, incl	0.03	0.06
Carbon, max. limits over 0.80 to 1.05 per cent, incl	0.03	0.07
Manganese, max. limits up to 0.90 per cent, incl	0.05	0.05
Manganese, max. limits over 0.90 to 1.20 per cent, incl	0.05	0.10
Manganese, max. limits over 1.20 to 1.65 per cent, incl	0.10	0.15
Phosphorus	....	0.01
Sulfur: In all grades except free-cutting steel grades	....	0.01
Sulfur: In free-cutting steel grades sulfur shall not vary more than 0.01 per cent under the minimum percentage specified.		

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Welded and Seamless Steel Pipe (A.S.T.M. Designation: A 53 – 33):[2]

Section 1.—Add the following paragraph as Paragraph (*b*), lettering the present section as Paragraph (*a*):

(*b*) *Galvanized Pipe.*—When pipe ordered under these specifications is to be galvanized, the tension, flattening and bend tests shall be made on the base material before galvanizing, and the pipe will be galvanized and the coating tested in accordance with the Standard Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A.S.T.M. Designation: A 120 – 34 T) of the American Society for Testing Materials.[3] When specified, results of the physical tests of the base material shall be reported to the purchaser.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 604 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 97.

NOTE.—If impracticable to make the physical tests on the base material before galvanizing, such tests may be made on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection.

Revision submitted, June, 1934; Modified, June, 1935.

Section 5 (a).—In the table of physical properties, appearing in this section, change the minimum elongation in 2 in. specified for the open-hearth or electric-furnace seamless low-carbon grade of pipe from the present requirement of "30 per cent" to read "35 per cent."

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A.S.T.M. Designation: A 83 – 34):[2]

Tables I and II.—Change these tables from their present form to read as follows:

TABLE I.—STANDARD WEIGHTS OF LAP-WELDED AND SEAMLESS BOILER TUBES.
INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

Thickness		Weight, lb. per ft. of Length										
		Outside Diameter, in.										
B.w.g.	In.	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
13	0.095	1.426	1.552	1.679	1.806	1.933	2.186	....	....	....	....	....
12	0.109	1.619	1.765	1.910	2.056	2.201	2.492	2.783	3.074	3.365	3.657	3.948
11	0.120	1.769	1.929	2.089	2.249	2.409	2.730	3.050	3.371	3.691	4.011	4.332
10	0.134	1.955	2.134	2.313	2.492	2.670	3.028	3.386	3.744	4.102	4.459	4.817
9	0.148	2.137	2.335	2.532	2.730	2.927	3.323	3.718	4.113	4.508	4.903	5.298
8	0.165	2.353	2.573	2.793	3.013	3.234	3.674	4.115	4.555	4.996	5.436	5.877
7	0.180	2.538	2.778	3.018	3.258	3.499	3.979	4.460	4.941	5.421	5.902	6.382
6	0.203	2.812	3.083	3.354	3.625	3.896	4.438	4.980	5.522	6.064	6.606	7.148
5	0.220	....	....	....	....	4.182	4.770	5.357	5.944	6.532	7.119	7.707
4	0.238	....	....	....	....	4.479	5.114	5.750	6.385	7.021	7.656	8.291
3	0.258	....	....	....	....	4.816	5.507	6.199	6.890	7.582	8.273	8.965
2	0.284	....	....	....	....	....	5.963	6.721	7.480	8.238	8.996	9.755
1	0.300	....	....	....	....	....	6.248	7.049	7.850	8.651	9.452	10.25

B.w.g.	In.	$3\frac{3}{4}$	4	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{3}{8}$	$5\frac{1}{2}$	6	7	8	9	10
11	0.120	4.652	....	....	....	....	....	....	....	....	....	....	....
10	0.134	5.175	5.533	6.248	6.964	7.322	7.500	7.679	....	....	....	....	....
9	0.148	5.693	6.089	6.879	7.669	8.064	8.262	8.460	....	....	....	....	....
8	0.165	6.317	6.758	7.639	8.520	8.961	9.181	9.401	10.28	12.04	13.81	....	....
7	0.180	6.863	7.344	8.305	9.266	9.747	9.987	10.23	11.19	13.11	15.03	16.96	....
6	0.203	7.690	8.232	9.316	10.40	10.94	11.21	11.48	12.57	14.74	16.90	19.07	21.24
5	0.220	8.294	8.881	10.06	11.23	11.82	12.11	12.41	13.58	15.93	18.28	20.63	22.98
4	0.238	....	....	....	....	....	....	....	14.65	17.19	19.73	22.27	24.81
3	0.258	....	....	....	....	....	....	....	....	....	....	24.18	26.94
2	0.284	....	....	....	....	....	....	....	....	....	....	....	29.47

NOTE.—Charcoal iron tubes are at present not available above 6 in. in outside diameter.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1934 Supplement to Book of A.S.T.M. Standards.

TABLE II.—STANDARD WEIGHTS OF SMALL SUPERHEATER TUBES.
SEAMLESS ONLY.

Thickness		Weight, lb. per ft. of Length													
		Outside Diameter, In.													
B.w.g.	In.	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
18....	0.049	0.3014	0.3344	0.3668	....	....	....	....	....	....	....	....	....	....	....
17....	0.058	0.3512	0.3902	0.4287	....	....	....	....	....	....	....	....	....	....	....
16....	0.065	0.3888	0.4325	0.4755	....	....	....	....	....	....	....	....	....	....	....
15....	0.072	0.4252	0.4737	0.5214	....	....	....	....	....	....	....	....	....	....	....
14....	0.083	0.4805	0.5363	0.5913	0.6471	0.7021	0.7579	0.8129	....	....	....	....	....	....	....
13....	0.095	0.5377	0.6017	0.6646	0.7285	0.7914	0.8553	0.9182	1.045	1.109	1.172	1.299	1.363	1.426	1.552
12....	0.109	0.6007	0.6740	0.7462	0.8195	0.8917	0.9651	1.037	1.183	1.256	1.328	1.474	1.547	1.619	1.765
11....	0.120	0.6472	0.7279	0.8074	0.8881	0.9676	1.048	1.128	1.288	1.369	1.448	1.608	1.689	1.769	1.929
10....	0.134	0.7027	0.7928	0.8816	0.9717	1.060	1.151	1.239	1.418	1.508	1.597	1.776	1.866	1.955	2.134
9....	0.148	....	....	....	....	1.149	1.249	1.347	1.544	1.644	1.742	1.939	2.039	2.137	2.335
8....	0.165	....	....	....	....	....	....	....	....	....	1.912	2.132	2.243	2.353	2.573
7....	0.180	....	....	....	....	....	....	....	....	....	....	....	....	2.538	2.778
6....	0.203	....	....	....	....	....	....	....	....	....	....	....	....	2.812	3.085

Section 17 (*b*).—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

(*b*) On tubes less than $1\frac{1}{4}$ in. in diameter and on all tubes under 3 ft. in length, the name, [or] initials, or brand of the manufacturer, ***the grade and hydrostatic pressure in pounds at which it was tested*** shall be legibly stenciled or indicated on a sticker applied on each tube.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Carbon-Steel Castings (A.S.T.M. Designation: A 27 – 24):[2]

The Tentative Specifications for Carbon-Steel Castings for Miscellaneous Industrial Uses (A 180 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications A 27 – 24.

Tentative Revision[1] of Standard Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A.S.T.M. Designation: A 95 – 33):[2]

Explanatory Note.—Change the Explanatory Note at the end of these specifications to read as follows:

NOTE.—Allowable pressures and their corresponding allowable temperatures are given in the following table. Higher temperatures with appropriate pressures may be used at the discretion of the designing engineer.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] See p. 568.

TABLE I.—MAXIMUM SERVICE PRESSURES FOR POWER PIPING AND OIL PIPING AT TEMPERATURES BELOW AND ABOVE 750 F.

Primary Service Pressure Rating at 750 F., lb. per sq. in.	100	300	400	600	900	1500
SERVICE TEMPERATURE, DEG. FAHR.	MAXIMUM SERVICE PRESSURES, LB. PER SQ. IN.					
POWER PIPING AND OIL PIPING						
100	230	500	670	1000	1500	2500
150	220	480	640	960	1440	2400
200	210	465	620	930	1395	2325
250	200	450	600	900	1350	2250
300	190	435	580	870	1305	2175
350	180	420	560	840	1260	2100
400	170	405	540	810	1215	2025
450	160	390	520	780	1170	1950
500	150	375	500	750	1125	1875
550	140	360	480	720	1080	1800
600	130	345	460	690	1035	1725
650	120	330	440	660	990	1650
700	110	315	420	630	945	1575
750	100	300	400	600	900	1500
POWER PIPING						
800	85	250	335	500	750	1250
850	70	200	270	400	600	1000
OIL PIPING						
800	92	275	370	550	830	1380
850	82	245	330	490	740	1230
900	70	210	280	420	630	1050
950	55	165	220	330	495	825
1000	40	120	160	240	360	600

Reference may be made to the dimensional standards for hydraulic pressure ratings and corresponding temperatures formulated by the Sectional Committee on Standardization of Pipe Flanges and Fittings, under the procedure of the American Standards Association, A.S.A. Project B 16 and more specifically to the American Standard for Steel Flanged Fittings and Companion Flanges, B 16*e* – 1932. Copies of this American Standard are obtainable from the American Standards Association or from the American Society of Mechanical Engineers, 29 West 39th St., New York City.

Revision submitted, June, 1934; Modified, August, 1934.

Tentative Revision[1] of Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A.S.T.M. Designation: A 96 – 33):[2]

Section 16.—Change this section to read as follows by the addition of the italicized words, the chemical requirements remaining the same:

16. Bolts and studs shall be equipped with semifinished nuts of American Standard heavy dimensions, chamfered and trimmed. *Nuts shall be made by the cold-punched or hot-forged, cold-trimmed process; nuts cut from drawn or rolled bar stock shall not be permitted.* If washers are used under nuts, they shall

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

be of forged or rolled steel. All nuts and washers shall be free from injurious defects and shall have a workmanlike finish. Nuts shall conform to the chemical requirements for phosphorus and sulfur as follows:

Revision submitted, June, 1934.

Section 17.—Change this section to read as follows by the addition of the italicized words:

17. American National Standard coarse screw threads shall be used, except that no stud ***or bolt*** shall have less than eight threads per inch.

Revision submitted, June, 1934.

Explanatory Note.—Make the same change in the Explanatory Note, appearing at the end of these specifications, as is recommended in the Explanatory Note of Specifications A 95 – 33, above.

Tentative Revision[1] of Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A.S.T.M. Designation: A 105 – 33):[2]

Class A Flanges.—Delete from these specifications all requirements for Class A flanges. This deletion will require adjustment of the following sections: 1 (*b*), 5 (*a*) and (*b*), 6 (*a*) and (*b*), 9 (*a*) and Explanatory Note 2. In order to avoid the inconsistency of having Classes *B* and *C* referred to with no Class *A*, redesignate the two remaining classes of flanges as Classes I and II.

Revision submitted, June, 1934.

Explanatory Note.—Make the same change in the Explanatory Note 1, appearing at the end of these specifications, as is recommended in the Explanatory Note of Specifications A 95 – 33, above.

Tentative Revision[1] of Standard Specifications for Chilled Cast-Iron Wheels (A.S.T.M. Designation: A 46 – 24):[2]

The Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 30 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications A 46 – 24.

Tentative Revision[1] of Standard Specifications for Wrought-Iron Plates (A.S.T.M. Designation: A 42 – 30):[2]

The Tentative Specifications for Wrought-Iron Plates (A 42 - 34 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard A 42 – 30.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 976 (1930); also 1935 Book of A.S.T.M. Tentative Standards, p. 256.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 648 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 220.

Tentative Revision[1] of Standard Specifications for Common Iron Bars (A.S.T.M. Designation: A 85 – 27):[2]

Section 11 (b).—Change to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

(*b*) If any [test specimen from the bar] *of the specimens* originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen *fails to meet the physical requirements of Section 4 and* breaks outside the middle third of the gage length, *as indicated by scribe scratches marked on the specimen before testing*, the individual [bar] *specimen* shall be rejected and one retest from a different bar will be allowed.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Refined Wrought-Iron Bars (A.S.T.M. Designation: A 41 – 30):[2]

Section 9 (b).—Change to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

(*b*) If any [test specimen from the bar] *of the specimens* originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen *fails to meet the physical requirements of Section 2 and* breaks outside the middle third of the gage length, *as indicated by scribe scratches marked on the specimen before testing*, the individual [bar] *specimen* shall be rejected and one retest from a different bar will be allowed.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Staybolt, Engine-Bolt and Other High-Grade Wrought-Iron Bars (A 84 – 33):[2]

Section 7 (a).—Change to read as follows by the addition of the italicized words and the omission of the words and figures in brackets:

7. (*a*) Grade A.—For bars $\frac{7}{8}$ in. in diameter *or under*, a reduction in the minimum elongation in 8 in. specified in Section 6 (*a*) shall be permitted, but in no case shall the elongation be less than 28 per cent. [For bars $\frac{3}{4}$ in. or under in diameter, the elongation shall not be less than 25 per cent.]

Revision submitted, June, 1935.

Section 11 (b).—Change to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

(*b*) If any [test specimen from the bars] *of the specimens* originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen *fails to meet the physical requirements of Section 6 and* breaks outside the middle third of the gage length, *as indicated by scribe scratches marked on the specimen before testing*, the individual [bar] *specimen* shall be rejected and one retest from a different bar will be allowed.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A.S.T.M. Designation: A 73 – 30):[2]

Title.—Omit the words "for Locomotives and Cars" from the title.

Section 1.—Change from its present form: namely,

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

1. These specifications cover two classes of wrought-iron blooms and forgings for locomotives and cars, as determined by the kind of material used in their manufacture: namely,

Class A, as defined in Section 2 (*a*);
Class B, as defined in Section 2 (*b*).

to read as follows:

1. These specifications cover two classes of wrought-iron blooms and forgings as determined by the kind of material used in their manufacture: namely,

Class A.—For locomotives, railroad cars and miscellaneous uses.
Class B.—For miscellaneous uses other than locomotive and railroad cars.

Revision submitted, June, 1935.

Section 9.—Add the following paragraph as a new Paragraph (*b*), lettering the present paragraph as Paragraph (*a*):

(*b*) If any of the specimens originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen fails to meet the physical requirements of Section 6 and breaks outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, the individual specimen shall be rejected and one retest from a different bloom or forging will be allowed. Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Hollow Rolled Staybolt Iron (A.S.T.M. Designation: A 86 - 35):[2]

Section 10 (*b*).—Change to read as follows by the addition of the italicized words and figure and the omission of the words in brackets:

(*b*) If any of the [samples] *specimens* originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen *fails to meet the physical requirements of Section 5 and* breaks outside the middle third of the gage length, *as indicated by scribe scratches marked on the specimen before testing*, the individual [sample] *specimen* shall be rejected and one retest from a different bar or bolt will be allowed.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Methods of Test for Magnetic Properties of Iron and Steel (A.S.T.M. Designation: A 34 - 33):[3]

Section 1.—Change the definitions which appear in this section to correspond to the definitions given in the Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 - 35 T).[4]

Revision submitted, June, 1935.

Section 2 (*d*).—Omit from this section the last two sentences, which read as follows:

When the material is to be used with the flux at approximately 45 deg. with reference to the direction of rolling of the sheets, it is permissible by mutual agreement between the manufacturer and purchaser to make permeability tests of strips cut on an angle of 45 deg. to the direction of rolling. (Only one type of strip will then be necessary for such tests.)

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1935 Supplement to Book of A.S.T.M. Standards.

[3] 1933 Book of A.S.T.M. Standards, Part I.

[4] See p. 726.

Add the following note at the end of the revised Section 2 (*d*):

NOTE.—When the material is to be used with the flux in any one direction with respect to the direction of rolling or has preferred properties in any one direction with respect to the direction of rolling, strips may be cut in a specified direction if there is mutual agreement between manufacturer and purchaser. (Only one type of strip will then be necessary for such tests.)

Revision submitted, June, 1935.

Section 5 (*c*).—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

(*c*) For permanent magnet steel, the residual induction and coercive force shall be determined from the maximum normal induction corresponding to a magnetizing force of 300 oersteds, unless from a maximum magnetizing force of 300 oersteds the coercive force is 100 oersteds or more, in which case [the maximum magnetizing force shall be 1000 oersteds] *a higher maximum magnetizing force shall be used as agreed upon by the manufacturer and purchaser.*

Revision submitted, June, 1935.

Section 6.—Add the following paragraphs to this section as Paragraphs (*g*) and (*h*):

(*g*) *The Simplex Super-H Adapter.*—This type of apparatus is suitable for tests at magnetizing forces between 100 and 2500 oersteds.

(*h*) *Saturation Permeameter.*—This type of apparatus is suitable for tests at magnetizing forces between 100 and 2500 oersteds.

Revision submitted, June, 1935.

Section 10 (*a*).—Add the following note at the end of this paragraph:

NOTE.—It is permissible by mutual agreement between the manufacturer and purchaser to cut test specimens other than as specified above with respect to the direction of rolling. This should be done in accordance with the Note appearing in Section 2 (*d*). It must always be specifically stated when tests are so made.

Revision submitted, June, 1935.

Sections 18 and 20.—Add the following sentences to Paragraph (*b*) of these sections:

The magnetic properties of certain materials are known to drift to an appreciable extent with time after demagnetization. This characteristic should be taken into account when specifying test procedure.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A.S.T.M. Designation: A 127 – 34):[2]

The Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Definitions A 127 – 34.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1934 Supplement to Book of A.S.T.M. Standards.

[3] See p. 726.

Tentative Revision[1] of Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (A.S.T.M. Designation: B 8 – 27):[2]

The Tentative Specifications for Bare Stranded Copper Cable: Hard, Medium-Hard or Soft (B 8 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications B 8 – 27.

Tentative Revision[1] of Standard Specifications for Bronze Trolley Wire (A.S.T.M. Designation: B 9 – 32):[2]

The Tentative Specifications for Bronze Trolley Wire (B 9 – 35 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications B 9 – 32.

Tentative Revision[1] of Standard Specifications for Copper Trolley Wire (A.S.T.M. Designation: B 47 – 32):[2]

Fig. 1.—Replace the illustration now appearing in the specifications which shows permissible variations in the dimensional requirements of the standard sections of grooved trolley wire, by the accompanying Fig. 1.[5]

Tentative Revision[1] of Standard Specifications for Slab Zinc (Spelter) (A.S.T.M. Designation: B 6 – 33):[2]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

1. These specifications cover [Virgin Spelter, that is,] slab zinc (spelter) made from ore or [similar raw] *other* material by a process of [reduction and] distillation or by electrolysis, and not produced [from reworked metal] *by "sweating" or remelting of secondary zinc*, in six grades, as follows:

(1a) Special High Grade
(1) High Grade
(2) Intermediate
(3) Brass Special
(4) Selected
(5) Prime Western

Revision submitted, June, 1935.

Section 2.—Change to read as follows by the omission of the words in brackets:

2. A brand shall be cast in each slab by which the maker [and grade] can be identified.

Revision submitted, June, 1935.

Section 4.—In the table of requirements as to chemical composition change the lead content for Special High Grade Zinc (Grade *1a*) from "0.010 per cent" to read "0.007 per cent"; also change the iron content for High Grade Zinc (Grade *1*) from "0.03 per cent" to read "0.02 per cent."

Revision submitted, June, 1935.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] See p. 736.

[4] See p. 740.

[5] See p. 743.

Section 8.—Change to read as follows by the addition of the italicized words:

8. Where the slab zinc (spelter) satisfies the chemical and physical requirements of these specifications, it shall not be condemned *for defects in manufacturing*, for defects of alloys in which it is used, or for defects in the coating of galvanized products.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (A.S.T.M. Designation: B 60 - 28):[2]

Title.—Omit the word "Sand" from the title.

Section 1.—Add to the scope clause the following sentence as a new Paragraph (*c*):

(*c*) It is recommended that this alloy shall not be used where castings are subjected to a temperature exceeding 260 C. (500 F.).

Section 3 (*a*).—Change the table of requirements as to chemical composition to read as follows by the addition of the italicized figures and the omission of those in brackets:

	DESIRED	MINIMUM	MAXIMUM
Copper, per cent	88.00	86.00	89.00
Tin, per cent	8.00	7.50	11.00
Lead, per cent	none	......	0.30
Zinc, per cent	4.00	1.50	4.50
Iron, per cent	[none]	......	*0.25* [0.10]
Nickel, per cent	......	......	*1.00* [0.50]
Phosphorus, per cent	......	......	0.05
[Aluminum, per cent]	[none]	......	[none]
[Sulfur, per cent]	[none]	......	[0.05]
[Antimony, per cent]	[none]	......	[0.25]
[Total other impurities, per cent]	[none]	......	[0.15]

Section 5 (*a*).—Change the table of requirements as to tensile properties to read as follows by the addition of the italicized figures and the omission of those in brackets:

Tensile strength, lb. per sq. in.	*38 000* [35 000]
Yield point, lb. per sq. in.	*16 000* [15 000]
Elongation in 2 in., per cent	*22* [15]

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Specifications for Composition Brass or Ounce Metal Sand Castings (A.S.T.M. Designation: B 62 - 28):[2]

Title.—Omit the word "Sand" from the title.

Section 3 (*a*).—Change the table of requirements as to chemical composition to read as follows by the addition of the italicized figures and the omission of those in brackets:

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

	DESIRED	MINIMUM	MAXIMUM
Copper, per cent	85.00	84.00	86.00
Tin, per cent	5.00	4.00	6.00
Lead, per cent	5.00	4.00	6.00
Zinc, per cent	5.00	4.00	6.00
Iron, per cent	[none]	......	0.25
Nickel, per cent	......	......	*1.00* [0.75]
Phosphorus, per cent	[none]	......	0.05
[Aluminum, per cent]	[none]	......	[none]
[Sulfur, per cent]	......	......	[0.05]
[Antimony, per cent]	......	......	[0.25]
[Total other impurities, per cent]	......	......	[0.15]

Section 5 (*a*).—Change the table of requirements as to tensile properties to read as follows by the addition of the italicized figures and the omission of those in brackets:

Tensile strength, lb. per sq. in.	*30 000* [26 000]
Yield point, lb. per sq. in.	*14 000* [12 000]
Elongation in 2 in., per cent	*20* [15]

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Specifications for Steam or Valve Bronze Sand Castings (A.S.T.M. Designation: B 61 – 28):[2]

Title.—Omit the word "Sand" from the title.

Revision submitted, August, 1934.

Section 3 (*a*).—Change the requirements as to chemical composition from their present form: namely,

	DESIRED	MINIMUM	MAXIMUM
Copper, per cent	88.00	86.00	91.00
Tin, per cent	6.50	6.00	7.00
Lead, per cent	1.50	1.00	2.00
Zinc, per cent	4.00	remainder	remainder
Iron, per cent	......	......	0.15
Nickel, per cent	......	......	0.50
Phosphorus, per cent	......	......	0.05
Aluminum, per cent	none	......	none
Antimony, per cent	......	......	0.25
Sulfur, per cent	......	......	0.05
Total other impurities, in addition to those specified above, per cent	......	......	0.15

to read as follows:

Copper, min., per cent	86.5
Tin, per cent	5.5 to 6.5
Lead, per cent	1.5 to 2.0
Zinc, per cent	2 to 5
Iron, max., per cent	0.25
Nickel, max., per cent	1.00
Phosphorus, max., per cent	0.05

Revision submitted, August, 1934.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

Section 5 (a).—Change the table of requirements as to tensile properties to read as follows by the addition of the italicized figures and the omission of those in brackets:

Tensile strength, lb. per sq. in.	*34 000* [32 000]
Yield point, lb. per sq. in.	16 000
Elongation in 2 in., per cent	*22* [17]

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings (A.S.T.M. Designation: B 45 – 27):[2]

The Tentative Method of Determination of Phosphorus in Copper-Base Alloys in Ingot Form for Sand Castings (B 45 – 33 T)[3] is in effect a tentative revision of and is intended when adopted to be incorporated in the present Standard Methods B 45 – 27.

Tentative Revision[1] of Standard Specifications for Quicklime for Structural Purposes (A.S.T.M. Designation: C 5 – 26):[4]

The Tentative Specifications for Quicklime for Structural Purposes (C 5 – 34 T)[5] are in effect a tentative revision of and are intended to replace when adopted the present Standard C 5 – 26.

Tentative Revision[1] of Standard Specifications for Hydrated Lime for Structural Purposes (A.S.T.M. Designation: C 6 – 31):[4]

The Tentative Specifications for Hydrated Lime for Structural Purposes (C 6 – 34 T)[5] are in effect a tentative revision of and are intended to replace when adopted the present Standard C 6 – 31.

Tentative Revision[1] of Standard Specifications for Concrete Sewer Pipe (A.S.T.M. Designation: C 14 – 35):[6]

Section 1.—Add the following footnote:

Caution.—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction.

Revision submitted, June, 1924.

Tentative Revision[1] of Standard Specifications for Fireclay Brick for Marine Boiler Service (A.S.T.M. Designation: C 65 – 28):[4]

These specifications contain requirements for softening point of clay refractories. Since this property of fire clay, fire brick and silica cement is now known as pyrometric cone equivalent it is proposed that the term "softening point" as it appears in these specifications be changed to read "pyrometric cone equivalent."

Revision submitted, June, 1933.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part I.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 638 (1933); also 1935 Book of A.S.T.M. Tentative Standards, p. 323.

[4] 1933 Book of A.S.T.M. Standards, Part II.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 749, 752 (1934); also 1935 Book of A.S.T.M. Tentative Standards, pp. 443, 446.

[6] 1935 Supplement to Book of A.S.T.M. Standards.

Tentative Revision[1] of Standard Specifications for Building Brick (Made from Clay or Shale) (A.S.T.M. Designation: C 62 – 30):[2]

The Tentative Specifications for Building Brick (Made from Clay or Shale) (C 62 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications C 62 – 30.

Tentative Revision[1] of Standard Methods of Testing Brick (Compression, Flexure, Absorption) (A.S.T.M. Designation: C 67 - 31):[2]

The Tentative Methods of Testing Brick (Modulus of Rupture, Compressive Strength, Absorption) (C 67 – 35 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard Methods C 67 – 31.

Tentative Revision[1] of Standard Method of Test for Refractory Materials Under Load at High Temperatures (A.S.T.M. Designation: C 16 – 20):[2]

Section 2 (*d*).—Add the following as a second paragraph of the present Paragraph (*d*):

> If the optical pyrometer is used, observations shall be made by sighting into a refractory tube having a closed end in the same relative position to the test specimen as that specified for the thermocouple.

Revision submitted, June, 1933.

Tentative Revision[1] of Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C 41 – 33):[2]

Section 2 (*b*).—Change to read as follows by the addition of the italicized word and figures and the omission of the word and figures in brackets:

> (*b*) Coarse aggregate, or a mixture of fine and coarse [aggregates] *aggregate*, weight in grams [3000] *10,000* times the size of the largest sieve required, measured in inches.

Revision submitted, June, 1935.

Section 5 (*a*).—Change from its present form: namely,

> 5. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Section 4. Sieving shall be continued until not more than 1 per cent by weight of the residue passes any sieve during 1 min.

to read as follows:

> 5. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Section 4. The sieving operation shall be conducted by means of a lateral and vertical motion of the sieve, accompanied by jarring action so as to keep the sample moving continuously over the surface of the screen. In no case shall fragments in the sample be turned or manipulated through the screen by hand. Sieving shall be continued until not more than 1 per cent by weight of the residue passes any sieve during 1 min. On that portion of the sample retained on the No. 4 sieve, the above described procedure for determining thoroughness of sieving shall be carried

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] See p. 788.

[4] See p. 791.

out with a single layer of material. When sieving machines are used, their thoroughness of sieving shall be tested by using hand methods of sieving as above described.

NOTE.—When samples of fine aggregate contain more than 2 per cent silt, it is recommended that the Tentative Method of Test for Amount of Material Finer than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117 – 35 T) of the American Society for Testing Materials[6] be made prior to and on the same sample as the sieve analysis.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Method of Test for Determination of Voids in Fine Aggregate for Concrete (A.S.T.M. Designation: C 30 – 22):[2]

The Tentative Method of Test for Determination of Voids in Coarse Aggregates (C 30 – 35 T)[3] is intended to be included, when adopted, with the present Standard Method C 30 – 22.

Tentative Revision[1] of Standard Definitions of Terms Relating to Sewer Pipe (A.S.T.M. Designation: C 8 – 24):[2]

The Tentative Definitions of Terms Relating to Clay Sewer Pipe (C 8 – 35 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard Definitions C 8 – 24.

Tentative Revision[1] of Standard Definitions for Fireclay Refractories (A.S.T.M. Designation: C 27 – 35):[5]

Add the following new definition:

Super Duty Fire-Clay Brick.—The Pyrometric Cone Equivalent of super duty fire-clay brick shall not be lower than that of Standard Pyrometric Cone No. 33, when tested on the fired product. The alumina content shall be not less than 40 per cent. In the panel spalling test, these brick shall not lose more than 1.0 per cent. In the test for permanent linear change after reheating, schedule C, the brick shall not show more than 0.5 per cent shrinkage.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Definitions of Terms Relating to Refractories (A.S.T.M. Designation: C 71 – 35):[5]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Refractories (C 71 – 35 T)"[6] are intended to be added when adopted to the present Standard Definitions C 71 – 35.

Tentative Revision[1] of Standard Definitions of Terms Relating to the Gypsum Industry (A.S.T.M. Designation: C 11 – 28):[2]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 31 T)"[7] are intended to be added when adopted to the present Standard Definitions C 11 – 28.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] See p. 846.

[4] See p. 829.

[5] 1935 Supplement to Book of A.S.T.M. Standards.

[6] See p. 811.

[7] *Proceedings*, Am. Soc. Testing Mats., Vol. 31, Part I, p. 749 (1931); also 1935 Book of A.S.T.M. Tentative Standards, p. 457.

Tentative Revision[1] of Standard Definition of the Term Sand (A.S.T.M. Designation: C 58 – 28):[2]

The Tentative Definition of the Term Aggregate (C 58 – 28 T)[3] is intended to be included, when adopted, with the present Standard Definition C 58 – 28.

Tentative Revision[1] of Standard Specifications for Raw Tung Oil (A.S.T.M. Designation: D 12 – 33):[2]

Section 1.—In the table of properties and tests change the requirement for specific gravity from its present form: namely,

	MAXIMUM	MINIMUM
Specific Gravity at 15.5°/15.5° C.	0.943	0.9400

to read as follows:

Specific Gravity at 15.5/15.5 C.	0.943	0.940[a]

[a] For American grown tung oil the minimum specific gravity may be as low as 0.938.

Revision submitted, June, 1935.

Section 3.—Change the descriptions of the heating test and the quality test described in Paragraphs (*h*) and (*i*), respectively, from their present form to read as follows:

(*h*) *Heating Test.*—The test tubes for the oil shall be 15 cm. by 16 mm., with a mark near the bottom to indicate 5 ml. Each tube shall be closed by a cork so perforated that a glass rod 3 mm. in diameter may be moved freely. The tubes shall each weigh 14.5 ± 2.0 g. (The purpose of this requirement is to control the wall thickness.)

Fill a 1000-ml. tall-form glass beaker (height 19 cm., diameter about 9 cm.) with cottonseed oil or other suitable oil to a height of 11 cm. Place the thermometer as shown in Fig. 1 so that the bottom will be level with the bottoms of the test tubes.

Use a nitrogen-filled, chemical thermometer, engraved stem, total length 4 to 4½ in., graduated from 210 to 310 C. in 2 C. intervals; the length between 210 and 310 C. not less than 2½ in. Thermometer glass shall be well annealed. This thermometer may be suspended in the bath by a wire or may be sealed to a glass rod as shown in Fig. 1.

When the bath temperature is 293 C. (560 F.) and very slowly rising at this point, place the tube containing 5 ml. of the oil to be tested and the tube containing 5 ml. of a control sample of known value into the large holes of the cover. Note the time. Remove the source of heat for about 45 sec. and then re-apply. Before 2 min. have elapsed the temperature of the bath will have fallen to 282.2 C. (540 F.), at which point it should be kept as steady as possible. When the samples have been in the bath 9 min. raise the glass rods at intervals of 15 sec. Note the time when each sample becomes firmly set. At this period the oil will be so stiff that the entire tube may be lifted by aid of the rod. As setting or jellying takes place within a few seconds of fluidity, a good end point is afforded. Remove the samples. Heat the bath again to 293 C. (560 F.), and repeat the experiment with fresh portions of the sample.

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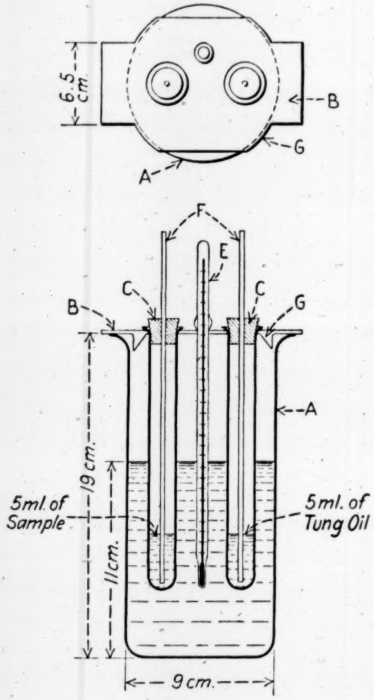
[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 835 (1928); also 1935 Book of A.S.T.M. Tentative Standards, p. 616.

No stirrer is used in the bath. A screen around the bath enables the temperature to be reached more easily. When the bath oil has become tarry and viscid, it should be renewed; otherwise heating may be irregular.



A. 1000-ml. tall-form beaker, 9 cm. in diameter by 19 cm. in height.
B. Support plate about 6.5 cm. wide, made of Monel metal, aluminum or stainless steel.
C. Corks.
D. Test tubes 15 cm. by 16 mm.
E. Thermometer, range 210 to 310 C.
F. Glass rods 3 mm. in diameter.
G. Guide to prevent cover from slipping.

FIG. 1.—Tung Oil Heating Test Apparatus (Revised, 1935).

(*i*) *Quality Test.*[1]—The apparatus required for this test consists of an ordinary vitreous enameled iron casserole having a bottom diameter of 7.5 cm. (3 in.); a wide flange tripod with a 7.5-cm. (3-in.) opening (the object of the flange is to prevent super-heating of the sides of the casserole); a total-immersion chemical thermometer, range 30 to 300 C. and 14 to 15 in. in length.

Put into the casserole 150 g. of the oil and heat so that the temperature reaches 282.2 C. (540 F.) in 4 min. ±30 sec., stirring with the thermometer. Turn down the flame and hold the heat as near 282.2 C. ±1 C. (540 F. ± 2 F.) as possible, stirring with the thermometer, until on lifting the latter, the oil drops with a pronounced string, showing that polymerization has started. The time required after reaching 282.2 C. (540 F. ± 2 F.) until the string is noted, is the time of the heat test. For pure tung oils this will not exceed 8 min. As soon as the oil strings, remove the lamp and the thermometer, and stir with a stiff spatula until the oil is solid. After stringing, a pure tung oil will require not over 40 sec. more to become solid. When solid, allow to stand just 1 min., then turn out, upside down, on clean paper and cut at once with a clean spatula.

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[1] Based on Worstall test.

Pure tung oil gives a gel that is dry, not adhering to the spatula when cut, that is firm, crumbling under pressure of the spatula without sticking, and the cut portions should crumble under pressure like dry bread crumbs. Adulterated tung oil gives a gel that is soft, sticky, and which will not crumble.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Amyl Acetate (Synthetic) (A.S.T.M. Designation: D 318 – 33):[2]

The Tentative Specifications for Amyl Acetate (from Fusel Oil) (85 to 88 per cent Grade) (D 318 – 34 T)[3] are intended to be included, when adopted, with the present Standard D 318 – 33.

Tentative Revision[1] of Standard Methods of Testing Oleo-Resinous Varnishes (A.S.T.M. Designation: D 154 – 28):[2]

The Tentative Methods of Testing Oleo-Resinous Varnishes (Skinning Test, Alkali Resistance, Acid Number (D 154 – 35 T)[4] are in effect a tentative revision of and are intended to replace when adopted the present Standard Methods D 154 – 28.

Tentative Revision[1] of Standard Methods of Routine Analysis of Yellow and Orange Pigments Containing Chromium Compounds, Blue Pigments and Chrome Green (A.S.T.M. Designation: D 126 – 35):[2]

Section 25.—Change this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

25. The percentage of Prussian blue may be obtained with sufficient accuracy for commercial purposes by multiplying the percentage of nitrogen by [4.4] *3.404* or the percentage of [iron (in the absence of other iron pigments) by 3.03] *ammonia by 2.8.*

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Methods of Routine Analysis of White Linseed Oil Paints (A.S.T.M. Designation: D 215 – 35):[2]

Nature of the Thinner.—Add the following paragraph at the end of this section:

When the amount of turpentine in the thinner is small so that its presence is questionable, it may be detected by placing two drops of the distillate and 2 to 3 ml. of chloroform in a dry test tube and adding one drop of antimony pentachloride. A slow or slight change in color will indicate the absence of turpentine. A rapid change in color to a dark red or purple will indicate the possibility of turpentine. The iodine number for turpentine by the Wijs method under these conditions is approximately 340. An iodine number of 20 or over will give additional proof of the presence of turpentine and enable calculation of the approximate amount.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 878 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 676.

[4] See p. 887.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Definitions of Terms Relating to Paint Specifications (A.S.T.M. Designation: D 16 - 24):[2]

Add the following three new definitions of terms:

Screen (*Sieve*).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder, for use in separating material according to size.

> NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties should be taken care of in specifications.
>
> NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

Toughness.—That quality of a material which may be measured by the maximum impact which it will withstand without rupture.

Elasticity.—In the case of paint or varnish, that property which allows a film to follow, without rupture, changes in the extent and form of the surface to which it is applied.

Revision submitted, June, 1925; Modified, June, 1928.

Tentative Revision[1] of Standard Method of Test for Distillation of Crude Petroleum (A.S.T.M. Designation: D 285 - 33)[2]

Section 4.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

4. Thermometer.—The A.S.T.M. Low-Distillation Thermometer, conforming to the requirements specified in Section 6 (*a*) of the Standard Method of Test for Distillation of [Natural] Gasoline, *Naphtha, Kerosine, and Similar Petroleum Products* (A.S.T.M. Designation: D [216] *86*) of the American Society for Testing Materials shall be used.

Revision submitted, June, 1935.

Section 9.—Change Paragraphs (*a*) and (*d*) of this section and the footnote to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

(*a*) The condenser bath shall be filled with cracked ice and [sodium chloride or calcium chloride to form a freezing mixture that will cover the condenser tube and maintain a temperature between 0 and 10 F.] *enough water added to cover the condenser tube. The temperature shall be maintained between 32 and 34 F. (0 and 1.1 C.). Any other convenient cooling medium may be used provided these temperature conditions are maintained.*

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

(*d*) A [300-ml. sample] ***quantity*** of the oil[a] ***equivalent to 300 ml. at 60 F. (15.5 C.)*** shall be measured ***or weighed*** into the distillation flask by any suitable means. [For less viscous oils a pipette or graduate may be used. If the oil is decidedly viscous a sample equivalent to 300 ml. at 60 F. shall be weighed into the flask.] None of the liquid shall be permitted to flow into the vapor tube.

[The weight in grams of the 300-ml. sample shall then be calculated. (The weight in grams of 300 ml. of oil is equivalent to 300 times its specific gravity determined in accordance with Paragraph (*c*).)]

Revision submitted, June, 1935.

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[a] In case ***the*** water ***content of*** [in] the crude oil causes bumping, ***or in any case if the crude oil contains more than 2 per cent of water***, the sample shall be dehydrated by some suitable method, without loss of naphtha, before making the determination.

Section 11.—Change to read as follows by the omission of the sentences in brackets:

11. Results of duplicate tests in the crude-oil distillation should not differ from each other by more than 0.5 per cent. [In the naphtha distillation duplicate results obtained for initial boiling point and maximum temperature, respectively, shall not differ from each other by more than 6 F. (3.33 C.). Duplicate readings of the volume of distillate collected in the cylinder when each of the prescribed temperature points is reached should not differ by more than 2 ml.]

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester (A.S.T.M. Designation: D 93 - 22):[2]

Section 1.—Add the following sentence to the section on scope:

In addition, a modified form of this method as described in Section 6 is used for the determination of the flash point of cut-back asphalts and other viscous materials and suspensions of solids.

Revision submitted, June, 1935.

New Sections.—Add the following heading and three new sections at the end of this method:

DETERMINATION OF FLASH POINT OF CUT-BACK ASPHALTS AND OTHER VISCOUS MATERIALS AND SUSPENSIONS OF SOLIDS

6. *Apparatus.*—The apparatus shall consist of the following:

(*a*) Pensky-Martens tester as described in Section 2 (*a*), (*b*), and (*c*), except that the stirrer shall be mechanically operated to stir in a downward direction at a speed of 70 to 80 r.p.m.

(*b*) Low-range thermometer as specified in Section 2 (*d*), Table I.

7. *Procedure.*—The material to be tested and the tester shall be brought to a temperature 30 F. lower than the estimated flash point. The air space between the cup and the interior of the air bath shall be completely filled with water at the temperature of the tester and material. The temperature shall be raised throughout the duration of the test at a rate of not less than 4 nor more than 6 F. per min. With the exception of this requirement for rate of heating and the rate of stirring of 70 to

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

80 r.p.m., specified in Section 6 (*a*), the procedure shall be the same as that prescribed in the Standard Method of Test for Flash Point of Volatile Flammable Liquids (A.S.T.M. Designation: D 56) of the American Society for Testing Materials.

8. *Accuracy.*—Duplicate tests should not differ by more than 5 F.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Method of Test for Flash Point of Volatile Flammable Liquids (A.S.T.M. Designation: D 56 - 21):[2]

The Tentative Method of Test for Flash Point by Means of the Tag Closed Tester (D 56 – 35 T)[3] is in effect a tentative revision of and is intended to replace when adopted the present Standard Method D 56 – 21.

Tentative Revision[1] of Standard Method of Test for Saponification Number (A.S.T.M. Designation: (D 94 - 28):[2]

Section 1.—Add the following sentence and footnote at the end of the section on scope:

This method is not applicable in the presence of compounds of sulfur, phosphorus, halogens, or other elements that consume alkali.[a]

Revision submitted, June, 1935.

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[a] This method does not give an accurate indication of fatty material present, when the sample contains appreciable amounts of free sulfur, sulfurized oils, etc., which react with the alkali used in this test; such materials combine with potash to increase the saponification number. The presence of hydrogen sulfide as indicated by the odor near the end of the back titration in the saponification test is an indication that reactive sulfur or its compounds are present in the sample, and hence the saponification number obtained will be greater than required for the amount of fatty matter actually present. Unfortunately, in the case of reactive chlorine and phosphorus compounds, no simple indication is given during the test. A gravimetric determination of the actual amount of fatty acids is probably the most reliable method for such compounds (see Section 6 (*b*)).

Tentative Revision[1] of Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (A.S.T.M. Designation: D 88 - 33):[2]

The Tentative Method of Test for Viscosity by Means of the Saybolt Viscosimeter (D 88 – 35 T)[4] is in effect a tentative revision of and is intended to replace when adopted the present Standard Method D 88 – 33.

Tentative Revision[1] of Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287 - 33):[2]

Section 3.—Change the third to seventh sentences, inclusive, of this section from their present form, to read as follows:

The range may be any suitable portion of the interval between 0 and 100° A.P.I. (1.0760 to 0.6112 sp. gr.). The A.P.I. hydrometer scale shall be divided into 0.1°, numbered at each multiple of 1° and each fifth division denoted by a longer line. The specific gravity hydrometer scale shall be divided in 0.0005 of a unit of specific gravity, numbered at each multiple of 0.01 and each 0.001 division denoted by a longer line. The smallest scale subdivision shall not be less than 1 mm. (0.039 in.)

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] See p. 897.

[4] See p. 914.

or more than 2 mm. (0.079 in.) in width. The accuracy of calibration of the hydrometer shall be such that the error at any point of the scale shall not exceed the value of one smallest scale division.

Revision submitted, August, 1935.

Section 7.—Change the last sentence in the first paragraph from its present form: namely,

> If the product to be tested is easily volatile the sample, thermometer, hydrometer, and hydrometer cylinder shall be cooled to a sufficiently low temperature before testing to insure that no volatile fractions are lost during the necessary handling.

to read as follows:

> If the product to be tested has an initial boiling point below 250 F. (121.1 C.) the sample shall be cooled in a closed container before pouring into the hydrometer cylinder. The thermometer, hydrometer and hydrometer cylinder shall also be cooled.

Revision submitted, August, 1935.

Tentative Revision[1] of Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117 - 33):[2]

New Sections.—Add the following as new Sections 9 and 10, renumbering the remaining sections accordingly:

> 9. *Specific Gravity.*—The test for specific gravity shall be made in accordance with the Standard Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287) of the American Society for Testing Materials.[2]
>
> 10. *Color.*—The test to determine color shall be made in accordance with the Tentative Method of Test for Color of Lubricating Oils by Means of A.S.T.M. Union Colorimeter (A.S.T.M. Designation: D 155 - 34 T) of the American Society for Testing Materials.[3]

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (A.S.T.M. Designation: D 65 - 23):[2]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

> 4. The percentage of wear shall be not more than 12.0 per cent.

Revision submitted, June, 1924.

Section 6.—Change the last line of this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> [Retained on] *Passing* 2½-in. screen . . . not [less] *more* than [85] *15* per cent.

Revision submitted, June, 1924.

Section 7 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

Revision submitted, June, 1924.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 885 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 699.

Tentative Revision[1] of Standard Specifications for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (A.S.T.M. Designation: D 66 - 23):[2]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

4. The percentage of wear shall be not more than 15.0 per cent.

Revision submitted, June, 1924.

Section 6 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

Revision submitted, June, 1924

Tentative Revision[1] of Standard Specifications for Block for Granite Block Pavements (A.S.T.M. Designation: D 59 - 26):[2]

Section 3 (a).—Change to read as follows by the addition of the italicized words:

3. (*a*) The percentage of wear and the French coefficient of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Rock (A.S.T.M. Designation: D 2) of the American Society for Testing Materials, ***except that the sample shall be prepared by use of a press and the fragments shall be as uniform and as nearly cubical as practicable.***

Revision submitted, June, 1929.

Tentative Revision[1] of Standard Specifications for Block for Recut Granite Block Pavements (A.S.T.M. Designation: D 131 - 23):[2]

Section 3 (a).—Make the same change in this section as recommended in Section 3 (*a*) of Specifications D 59 - 26 above.

Revision submitted, June, 1929.

Tentative Revision[1] of Standard Specifications for Block for Durax Granite Pavements (A.S.T.M. Designation: D 132 - 23):[2]

Section 3 (a).—Make the same change in this section as recommended in Section 3 (*a*) of Specifications D 59 - 26 above.

Revision submitted, June, 1929

Tentative Revision[1] of Standard Specifications for Asbestos Yarns (A.S.T.M. Designation: D 299 - 33):[2]

The Tentative Specifications for Asbestos Yarns (D 299 - 34 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard D 299 - 33.

Tentative Revision[1] of Standard Specifications for Chafer Tire Fabrics (A.S.T.M. Designation: D 316 - 34):[4]

Section 1.—Change this section to read as follows by the addition of the italicized words and figures:

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, p. 1172 (1934); also 1935 Book of A.S.T.M. Tentative Standards, p. 1263.

[4] 1934 Supplement to Book of A.S.T.M. Standards.

1. These specifications cover commercial 8, 9, 12 and 14-oz. *plied yarn and 8.25, 11.65 and 14-oz. single yarn* chafer tire fabrics made of carded American cotton of the following constructions:

Add the following to the present tabulation of constructions which follows Section 1:

8.25 oz.........single yarn warp and filling.........clean white cotton, no waste
11.65 oz.........single yarn warp and filling.........clean white cotton, no waste
14.00 oz.........single yarn warp and filling.........clean white cotton, no waste

Revision submitted, August, 1934.

Table I.—Add to Table I the following requirements covering 8.25, 11.65 and 14-oz. single yarn chafer tire fabrics:

	8.25-oz. Single Yarn			11.65-oz. Single Yarn			14.00-oz. Single Yarn		
	Std.	Min.	Max.	Std.	Min.	Max.	Std.	Min.	Max.
Width, in.	60	59.5	60.5	60	59.5	60.5	60	59.5	60.5
Weight, oz. per sq. yd.	8.25	8.0	8.5	11.65	11.35	11.95	14.0	13.60	14.4
Count, Warp	32.0	31.3	32.7	32.0	31.3	32.7	23.0	22.5	23.5
Count, Filling	28.0	26.9	29.1	28.0	26.9	29.1	23.0	22.1	23.9
Thickness (Gage), in.	0.0290	0.0273	0.0307	0.0310	0.0295	0.0325	0.0390	0.0370	0.0410
Tensile Strength,[a] lb., Grab Test, Conditioned[b], Warp	....	95	....	....	145	....	....	160	....
Tensile Strength,[a] lb., Grab Test, Conditioned[b], Filling	....	95	....	....	155	....	....	170	....
Crimp, per cent, Warp	16.0	14.4	17.6	16.0	14.4	17.6	16.0	14.4	17.6
Crimp, per cent, Filling	9.0	7.2	10.8	9.0	7.2	10.8	9.0	7.2	10.8

[a] Tensile strength values are based on tests made on a 400 to 800-lb. capacity horizontal testing machine of inclination balance type.

[b] Preferred Method, in standard condition or corrected to standard moisture regain (6.5 per cent).

Revision submitted, August, 1934.

Tentative Revision[1] of Standard Specifications for Textile Testing Machines (A.S.T.M. Designation: D 76 – 33):[2]

The Tentative Specifications for Textile Testing Machines (D 76 – 35 T)[3] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications D 76 – 33.

Tentative Revision[1] of Standard Specifications for Tolerances and Test Methods for Tire Cord, Woven and on Cones (A.S.T.M. Designation: D 179 – 33):[2]

Section 26.—Change the last paragraph from its present form: namely,

A record shall be made of deviations from the scale or chart readings and corresponding corrections shall be made on the machine.

to read as follows:

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] See p. 1200.

When a machine is found to be in a satisfactory mechanical condition, meets the sensitivity requirements of Section 25 and then shows deviations between weights applied and dial readings, the following is considered a valid method of correction: Construct an empirical dial, the points on which shall be located by the position of the machine pointer after application of various weights as prescribed in this section.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Tolerances and Test Methods for Hose Ducks and Belt Ducks (A.S.T.M. Designation: D 181 - 34):[2]

Section 10.—Change from its present form: namely,

10. *Width.*—The average width shall be determined by measuring at five different places uniformly distributed along the full length of the roll. No measurement shall be considered within 3 yd. of either end of the roll.

to read as follows:

10. *Width.*—The width of the fabric shall be determined by measuring the cloth from selvage to selvage with the surface free of wrinkles. The measuring device shall be in excess of the width of the fabric. The width of the roll shall be the average of five different measurements uniformly distributed along the full length of the roll or piece.

Revision submitted, June, 1935.

Section 11.—Change from its present form to read as follows:

11. (*a*) The actual weight of the full roll from which the covering has been removed shall be determined.

(*b*) The specified weight of the full roll shall be determined from the following formula:

$$S = \frac{W \times A \times L}{36 \times 16}$$

where S = the specified weight in pounds
W = the specified weight in ounces per square yard
A = the actual width in inches
L = the actual length in yards

(*c*) Comparison of the actual weight with the specified weight of the full roll shall be used in determining the percentage light or heavy.

Revision submitted, June, 1935.

Tentative Revision[1] of Standard Specifications for Tolerances and Test Methods for Cotton Sewing Threads (A.S.T.M. Designation: D 204 - 33):[3]

New Section.—Add a new section on conditioning, as the first paragraph of the methods of testing section, to read as follows, renumbering the remaining sections accordingly:

Conditioning.—Spools or other types of packages selected for test shall be conditioned in an atmosphere having a relative humidity of 65 per cent at

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1934 Supplement to Book of A.S.T.M. Standards.

[3] 1933 Book of A.S.T.M. Standards, Part II.

70 F. (21 C.) for a minimum period of 12 hr. in the case of untreated threads, and for 40 hr. in the case of treated threads (such as waxed or glazed). Thread removed for testing after conditioning shall not penetrate into the package more than ¼ in. on a radial line. If skeins are prepared for testing they shall be conditioned for at least 3 hr. for untreated threads and for 10 hr. for treated threads. **Revision submitted, June, 1935.**

Section 8.—Change the first sentence to read as follows by the addition of the words and figures in italics and the omission of the word in brackets:

All threads shall be tested by the single strand [test] method ***in an atmosphere having a relative humidity of 65 per cent at 70 F. (21 C.).***

Revision submitted, June, 1935.

Section 9.—Change the first sentence to read as follows by the addition of the italicized words and figures:

In determining the yards per pound of sewing thread, the skeins shall be prepared in accordance with Table I ***after conditioning as noted in the new section on Conditioning above.*** **Revision submitted, June, 1935.**

Tentative Revision[1] of Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39 - 34):[2]

Tear Resistance Test.—Add as a new Section 14 the following tear resistance test procedure, renumbering the present sections accordingly:

(*H*) *Tear Resistance*

(*a*) *Preferred Method.*—A specimen 3 in. in width and 6 in. in length shall be selected for test. An isosceles trapezoid having an altitude of 3 in. and with bases 1 in. and 4 in. in length, respectively, shall then be marked on the specimen with the aid of a template. A cut ¼ to ⅜ in. in length shall then be made in the center of the 1-in. length and perpendicular to it. The specimen shall then be clamped in the jaws of the tensile strength testing machine along the non-parallel sides of the trapezoid. The initial distance between the jaws shall be 1 in., and the width of the jaws shall be 3 in. or more. One edge of the specimen shall thus be held taut while the other edge lies in folds. The machine shall then be started and the sample torn, the speed of the pulling jaw being 12 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been started shall be considered as the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

(*b*) *Alternate Method.*—A specimen 3 in. in width and 8 in. in length shall be selected for test. A longitudinal cut 3 in. in length shall be made in the center of the specimen. One of the tongues thus formed shall be placed in the upper jaw of a tensile strength testing machine, preferably with automatic recording device, and the other in the lower jaw. The machine shall then be started and the specimen torn, the speed of the pulling jaw being 12 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been started shall be considered to be the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

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[1] Criticisms of this revision are solicited and should be directed to the **Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.**

[2] 1934 Supplement to Book of A.S.T.M. Standards.

Revision submitted, June, 1930; Modified, June, 1933.

Elongation Test.—Add the following elongation test procedure as a new Section 15, renumbering the present sections accordingly:

(*I*) *Elongation*

Unless otherwise specified, the elongation of cloth at any stated load shall be obtained when the breaking strength is determined and for the same specimens by means of a suitable autographic recording device on the testing machine. The elongation shall be the average of the results obtained for five specimens. It shall be expressed as the percentage increase in length. Since the initial length and therefore the measured elongation depend upon the load applied in placing the specimen in the jaws of the machine, an initial load of 6 oz., or other initial load specified for the particular material in question, shall be placed on the specimen before clamping the specimen in the lower jaw of the machine. The elongation shall be calculated from the start of the line as shown on the graphic record.

Revision submitted, June, 1933; Modified, June, 1935.

Tentative Revision[1] of Standard Methods of Testing Molded Materials Used for Electrical Insulation (A.S.T.M. Designation: D 48 - 33):[2]

Section 10.—Change this section which describes the flexure test apparatus to read as follows by the addition of the italicized words and the omission of those in brackets:

10. Any standard testing machine may be used provided it is accurate to within 1 per cent for the lowest load for which it is used. The distance between points of support shall be 4 in. (102 mm.). The supports shall have the contact edges rounded to a radius of ⅛ in. (3.18 mm.). The load shall be applied [parallel to and in the same direction that] ***perpendicular to the direction in which*** the molding pressure was applied, midway between the supports by a pressure piece, the bearing edge of which shall be rounded to a radius of ⅛ in. (3.18 mm.).

Revision submitted, August, 1934.

Section 11.—Change this section from its present form: namely,

11. The test specimen shall be molded to the dimensions shown in Fig. 3.

to read as follows:

11. The test specimen shall be molded to the dimensions shown in Fig. 3. The thickness of the molded specimen, that is, the dimension parallel to the application of the molding pressure may be any value of ½ in. or less agreed upon as representative of the cross section in which the material is to be used. The thickness as molded will be the width of the beam when under test.

NOTE.—When the specimen is less than ¼ in. in molded thickness difficulties may be encountered due to tipping over or unsteadiness during test. In such cases the test may be made upon a composite specimen consisting of sufficient individual pieces to aggregate approximately ½ in. in beam width held together by a rubber band or other light clamp.

Revision submitted, August, 1934.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

Section 13.—Change this section to read as follows by the addition of the italicized words and the omission of those in brackets:

13. The report shall include the following:

(*a*) The thickness and width ***as molded*** of each specimen [as] measured by a micrometer in inches or millimeters;

(*b*) The load on each specimen in pounds or in kilograms at the first sign of failure;

(*c*) The maximum fiber stress in pounds per square inch or in kilograms per square millimeter calculated from the formula:

$$S = \frac{3Pl}{2bd^2}$$

in which S = maximum fiber stress, P = load applied, l = distance between [the supports] ***points of support,*** b = width of [specimen] ***the beam as tested,*** and d = depth of [specimen] ***the beam as tested;***

(*d*) The rate at which the load was applied;

(*e*) The maximum deflection at the center in inches or in millimeters.

Revision submitted, August, 1934.

Figure 3.—Change this figure which shows the flexure test specimen by omitting the ½-in. dimension under the side view and substituting the following note: "Thickness in accordance with Section 11." Add an arrow showing "direction of molding pressure" perpendicular to the remaining ½-in. dimension. Retain the note under the figure caption.

Revision submitted, August, 1934.

Resistance to Impact.—Add the following as a new Section 14, renumbering the remaining sections accordingly:

14. Resistance to impact shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Resistance to Impact (A.S.T.M. Designation: D 256 - 34 T) of the American Society for Testing Materials.[1]

Revision submitted, August, 1934.

Sections 14 to 17, inclusive.—Replace this material, describing dielectric strength tests at commercial power frequencies, by the following new Section 15, renumbering the present Sections 18 to 24, inclusive, accordingly:

DIELECTRIC STRENGTH

15. The dielectric strength shall be determined in accordance with the Tentative Methods of Testing Sheet, Tape, and Molded Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 - 34 T) of the American Society for Testing Materials.[1]

Revision submitted, June, 1934.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 34, Part I, pp. 995, 982 (1934); also 1935 Book of A.S.T.M. Tentative Standards, pp. 993, 980.

Tentative[1] Revision of Standard Definitions of Terms Relating to Coal and Coke (A.S.T.M. Designation: D 121 – 30):[2]

The Tentative Definition of the Term Coke (D 121 – 30 T)[3] is intended to be added when adopted to the present Standard Definitions D 121 – 30.

Tentative Revision[1] of Standard Definitions of Terms Relating to Timber Preservatives (A.S.T.M. Designation: D 324 – 33):[2]

The following definition of the term "water-gas tar" is intended when adopted to be added to the Standard Definitions D 324 – 33:

Water-Gas Tar.—Tar produced in the manufacture of carbureted water gas by the decomposition of petroleum oil by heat in the presence of blue gas.

Revision submitted, June, 1933.

Tentative Revision[1] of Standard Specifications for Round-Hole Screens for Testing Purposes (A.S.T.M. Designation: E 17 – 33):[4]

The Tentative Specifications for Round-Hole Screens for Testing Purposes (E 17 – 35 T)[5] are in effect a tentative revision of and are intended to replace when adopted the present Standard Specifications E 17 – 33.

Tentative Revision[1] of Standard Methods of Metallographic Testing of Iron and Steel (A.S.T.M. Designation: E 3 – 24):[4]

Tentative Revision[1] of Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (A.S.T.M. Designation: E 5 – 27):[4]

The Tentative Recommended Practice for Metallographic Testing of Ferrous and Non-Ferrous Metals (E 3 – 35 T)[6] is in effect a tentative revision of and is intended to replace when adopted the present Standard Methods E 3 – 24 and E 5 – 27.

Tentative Revision[1] of Standard Definitions of Terms Relating to Methods of Testing (A.S.T.M. Designation: E 6 – 30):[4]

The definitions of the terms "elastic limit" and "yield strength" published under the title "Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 35 T)[7] are intended to be added when adopted to the present Standard Definitions E 6 – 30.

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[1] Criticisms of this revision are solicited and should be directed to the Headquarters of the Society, 260 S. Broad St., Philadelphia, Pa.

[2] 1933 Book of A.S.T.M. Standards, Part II.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part I, p. 1147 (1930); also 1935 Book of A.S.T.M. Tentative Standards, p. 639.

[4] 1933 Book of A.S.T.M. Standards, Part I.

[5] See p. 1289.

[6] See p. 1319.

[7] See p. 1315.

SUPPLEMENT A (1935) TO A.S.T.M.
MANUAL ON PRESENTATION OF DATA[1]

PRESENTING ± LIMITS OF UNCERTAINTY OF AN OBSERVED AVERAGE

1. **Purpose.**—This Supplement[2] discusses the problem of presenting ± limits to indicate the uncertainty of the average of a number of observations obtained under the same essential conditions, and suggests a form of presentation for use in A.S.T.M. reports and publications where needed.

2. **The Problem.**—An observed average, $\bar{X}$, is subject to the uncertainties that arise from sampling fluctuations, and tends to vary from the true average more widely if the number, n, of observations is small.

TABLE I.—BREAKING STRENGTH OF 0.104-IN. HARD-DRAWN COPPER WIRE.

Test Specimen	Breaking Strength, X, lb.
1	578
2	572
3	570
4	568
5	572
6	570
7	570
8	572
9	596
10	584
$n = 10$	5752
Average, $\bar{X}$	575.2
Standard deviation, σ	8.26

Having a set of n observed values of a variable X whose average (arithmetic mean) is $\bar{X}$, as in Table I, it is often desired to present the results as

$$\text{Average, } \bar{X} = 575.2 \pm 5.1 \text{ lb.}$$

the ± limits being established from the quantitative data alone with the implication that the objective[3] average, $\bar{X}'$, of the universe sampled lies within such limits. How should such limits be computed, and what meaning may be attached to them?

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[1] 1933 Manual on Presentation of Data, sponsored by Committee E-1 on Methods of Testing, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 451 (1933); also published in pamphlet form.

[2] This Supplement is one of a series prepared by the Manual Committee of Technical Committee IX on Interpretation and Presentation of Data, of Committee E-1 on Methods of Testing.

Personnel of Manual Committee, 1934–1935:

Messrs. H. F. Dodge, Chairman
W. C. Chancellor
J. T. MacKenzie
R. T. Webster

The nomenclature is the same as that used in the 1933 A.S.T.M. Manual on Presentation of Data.

[3] The objective average, $\bar{X}'$, is the value of $\bar{X}$ that would be approached as a statistical limit as more and more observations were obtained under the same essential conditions, and their cumulative averages computed.

3. **Theoretical Background.**—Mention should be made of the practice, currently losing favor in scientific work, of recording such limits as

$$\bar{X} \pm 0.6745 \frac{\sigma}{\sqrt{n}}$$

where $\bar{X}$ = observed average,
σ = observed standard deviation, and
n = number of observations,

and referring to the value $0.6745 \frac{\sigma}{\sqrt{n}}$ as the "probable error" of the observed average, $\bar{X}$, (the value of 0.6745 corresponding to the Normal Law probability of 0.50). The term "probable error" and the probability value of 0.50 properly apply to the errors of sampling when sampling from a universe whose average, $\bar{X}'$, and whose standard deviation, σ', are *known* (these terms apply to limits $\bar{X}' \pm 0.6745 \frac{\sigma'}{\sqrt{n}}$), but they do not apply in the inverse problem when merely sample values of $\bar{X}$ and σ are given.

Recent investigation[1] of this problem has given the following more satisfactory alternative, a procedure which provides limits that have a definite operational meaning.

4. **Computation of Limits.**—The following procedure applies to any long run series of problems for each of which the following conditions are met:

Given: A sample of n observations, $X_1, X_2, X_3, \ldots, X_n$, having an average = $\bar{X}$ and a standard deviation = σ.

Conditions: (*a*) The universe sampled is homogeneous (statistically controlled) in respect to the variable, X, measured.

(*b*) The distribution of X for the universe sampled is approximately Normal.

(*c*) The sample is a random sample.[2]

Procedure: Compute limits

$$\bar{X} \pm a\sigma$$

where the value of a is given in Table II for two values of P_s and for various values of n.

Meaning: If the values of a given in Table II for $P_s = 0.90$ are used in a series of such problems, then, in the long run, we may expect 90 per cent of the ranges bounded by the limits so computed, to include the objective averages, $\bar{X}'$, of the universes sampled. If in each instance, we were to conclude that $\bar{X}'$ lies in the range so computed, we should expect to be correct 9 times in 10 and in error 1 time in 10. But, there would be no operational meaning in the following statement made in each instance: "The probability is 0.90 that $\bar{X}'$ falls within the limits computed in this case" since $\bar{X}'$ either does or does not fall within the limits."

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[1] W. A. Shewhart, "Probability as a Basis for Action," presented at the joint meeting of the American Mathematical Society and Section K of the A.A.A.S., December 27, 1932. See also E. S. Pearson, "Report on the Application of Statistical Methods to Industrial Standardization and Quality Control," British Standards Inst.

[2] If the universe sampled is *limited*, that is, made up of a definite number of separate units that may be measured in respect to the variable X, this procedure requires, in addition, that the number of units, n, in the sample be relatively small compared with the number of units, N, in the universe, say n less than 5 per cent of N.

TABLE II.—LIMITS WITHIN WHICH $\bar{X}'$ MAY BE EXPECTED TO LIE (9 TIMES IN 10, OR 99 TIMES IN 100), IN PROBLEMS INVOLVING A SINGLE SAMPLE OF *n* OBSERVATIONS.

Values of *a* computed from Table IV, "Table of *t*," in R. A. Fisher's, "Statistical Methods for Research Workers," based on Student's distribution of *z*.

Number of Observations in Sample, *n*	Limits, $\bar{X} \pm a\sigma$	
	$P_s = 0.90$ (Chances, 9 in 10)	$P_s = 0.99$ (Chances, 99 in 100)
	Value of *a*	Value of *a*
4	1.360	3.372
5	1.066	2.302
6	0.901	1.803
7	0.793	1.513
8	0.716	1.322
9	0.658	1.186
10	0.611	1.083
11	0.573	1.002
12	0.542	0.936
13	0.514	0.882
14	0.491	0.835
15	0.471	0.796
16	0.453	0.761
17	0.437	0.730
18	0.422	0.703
19	0.409	0.678
20	0.397	0.656
21	0.386	0.636
22	0.376	0.618
23	0.366	0.601
24	0.357	0.585
25	0.349	0.571
n greater than 25	$a = \frac{1.645}{\sqrt{n-3}}$ approximately	$a = \frac{2.576}{\sqrt{n-3}}$ approximately

The magnitude $P_s = 0.90$ applies to the *series of instances,* and is approached as a statistical limit as the number of instances in the series is increased indefinitely; hence it is labelled P_s, signifying "statistical probability."

If the values of *a* given in Table II for $P_s = 0.99$ are used, we may, in like manner, expect 99 per cent of the universe averages, $\bar{X}'$, to fall within the ranges so computed.

5. **Experimental Verification.**—Figure 1 gives two diagrams[1] illustrating the results of sampling experiments for samples of $n = 4$ observations each drawn from a Normal universe, for values of (*a*) $P_s = 0.50$ and (*b*) $P_s = 0.90$. For case (*a*), the ranges for 51 out of 100 samples included $\bar{X}'$ and for case (*b*), 90 out of 100 included $\bar{X}'$. If, in each instance (that is, for each sample) we had concluded that the objective $\bar{X}'$ lay within the limits shown for case (*a*), we would have been correct 51 times and in error 49 times, which is a reasonable variation from the expectancy of being correct 50 per cent of the time.

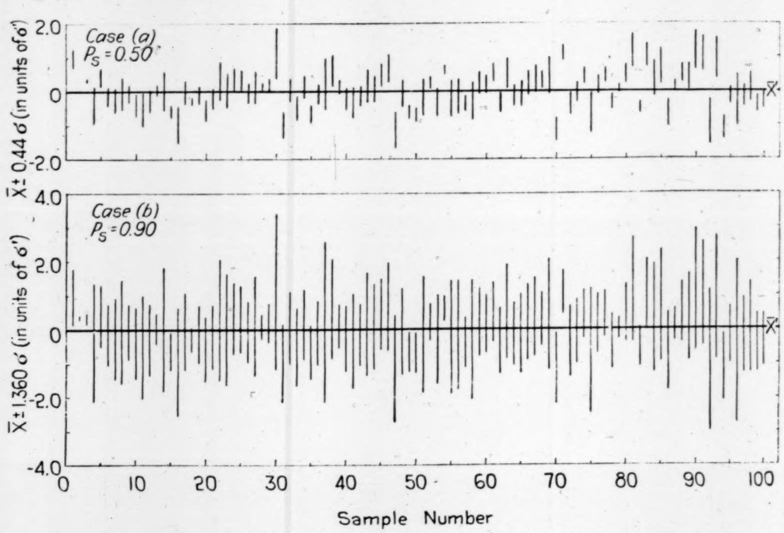

FIG. 1.—Illustration Showing Computed Ranges Based on Sampling Experiments. 100 samples of $n = 4$ observations each, from a normal universe having $\bar{X}' = 0$ and $\sigma' = 1$.

6. **Presentation of Data.**—In presentation of data, if it is desired to give limits of this kind, it is quite important that the significance of the limits be clearly indicated. The two values $P_s = 0.90$ and $P_s = 0.99$ given in Table II (chances of 9 in 10 and 99 in 100) are arbitrary choices that may be found convenient in practice.

Example: Given a sample of 10 observations of breaking strength of hard-drawn copper wire, as in Table I, for which

$$\bar{X} = 575.2 \text{ lb.}$$
$$\sigma = 8.26 \text{ lb.}$$

Using this sample to define limits within which we may feel confident (on the data evidence only) that $\bar{X}'$ lies and using the limits based on $P_s = 0.90$ (Table II), we have

$$\bar{X} \pm 0.611\sigma = 575.2 \pm 5.1$$
$$= 570.1 \text{ and } 580.3.$$

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[1] Case (*a*) is taken from Fig. 8 of Shewhart paper, *loc. cit.*, and case (*b*) gives corresponding ranges for limits $\bar{X} \pm 1.360\sigma$, based on $P_s = 0.90$.

Two pieces of information are needed to supplement this numerical result: (*a*) the fact that 9 in 10 limits were used, and (*b*) that this result is based solely on the evidence contained in 10 observations. Symbolically

$$\frac{P_s\,(\bar{X} \pm a\sigma)}{Q_x} = 0.90,$$

or the statistical probability associated with the limits $\bar{X} \pm a\sigma$, based on the evidence (Q_x) contained in the $n = 10$ observations, is 0.90.

Hence, in the presentation of such limits, it is desirable to give the results in some such way as the following:

575.2 ± 5.1 lb. ($P_s = 0.9$, 10 observations)

The essential information contained in the data is, of course, covered by presenting $\bar{X}$, σ, and n (see 1933 A.S.T.M. Manual on Presentation of Data) and the limits under discussion could be derived directly therefrom. If it is desired to present such limits in addition to $\bar{X}$, σ, and n, the tabular arrangement given below is suggested:

NUMBER OF TESTS	AVERAGE, $\bar{X}$	LIMITS FOR $\bar{X}$ (CHANCES, 9 IN 10)	STANDARD DEVIATION, σ
10..............................	575.2	±5.1	8.26

7. **Number of Places to be Retained in Computation and Presentation.**—The following working rule is recommended in carrying out computations incident to determining averages, standard deviations, and "limits for averages" of the kind here considered, for a set of *n* observed values of a variable quantity:

> In all operations on the set of *n* observed values, such as adding, subtracting, multiplying, dividing, squaring, extracting square root, etc., retain the equivalent of two more places of figures than in the single observed values. For example, if observed values are read or determined to the nearest 1 lb., carry numbers to the nearest 0.01 lb. in the computations; if observed values are read or determined to the nearest 10 lb., carry numbers to the nearest 0.1 lb. in the computations, etc.

Rejecting places of figures should be done after computations are completed, in order to keep the final results substantially free from computation errors. In rejecting places of figures, *increase by 1 the last figure retained when the first left-hand rejected figure is 5 or greater, otherwise, leave it unchanged.* For example, if, in the following numbers, the places of figures in parentheses are to be rejected,

39 4(49) becomes 39 400,
39 4(50) becomes 39 500, and
39 4(76) becomes 39 500.

The number of places of figures to be retained in presentation depends on what use is to be made of the results. No general rule, therefore, can safely be laid down. The following working rule has, however, been found generally satisfactory by the committee in presenting the results of testing in technical investigations and development work:

(*a*) For averages, retain the number of places shown below:

SINGLE VALUES OBTAINED TO THE NEAREST	NUMBER OF OBSERVED VALUES, n		
0.1, 1, 10, etc., units		2–20	21–200
0.2, 2, 20, etc., units	less than 4	4–40	41–400
0.5, 5, 50, etc., units	less than 10	10–100	101–1000
Number of places of figures to be retained in the average	Same number of places as in single values	1 more place than in single values	2 more places than in single values

(*b*) For standard deviations, retain three places of figures.

(*c*) If "limits for averages" of the kind here considered are presented, retain the same places of figures as are retained for the average.

For example, if $n = 10$, and if observed values were obtained to the nearest 1 lb., present averages and "limits for averages" to the nearest 0.1 lb., and present the standard deviation to three places of figures. This is illustrated in the tabular presentation in Section 6.

The above rule (*a*) will generally result in giving two doubtful places of figures in the average, where by "doubtful" is meant that the figures appearing in these places would not be duplicated exactly in additional samples taken under the same essential conditions. Referring to the tabular arrangement in Section 6, the third place of figures in the average, $\bar{X} = 575.2$, corresponding to the first place of figures in the ± 5.1 value is doubtful in the above sense. One might conclude that it would be suitable to present the average to the nearest pound, thus:

$$575 \pm 5 \text{ lb. } (P_s = 0.9, 10 \text{ observations}).$$

This might be satisfactory for some purposes. However, the effect of such rounding off to the first place of figures of the plus or minus value may be quite pronounced if the first digit of the plus or minus value is small, as indicated in the following table:

	NOT ROUNDED				ROUNDED		
	LIMITS		DIFFERENCE		LIMITS		DIFFERENCE
573.5 ± 1.4	572.1	574.9	2.8	574 ± 1	573	575	2
573.5 ± 1.5	572.0	575.0	3.0	574 ± 2	572	576	4

If further use were to be made of these data—accumulating additional observations to be combined with these, gathering other data to be compared with these, etc.—then the effect of such rounding off of $\bar{X}$ in a presentation might seriously interfere with proper subsequent use of the information.

The number of places of figures to be retained or to be used as a basis for action in specific cases (such as in reports covering the acceptance and rejection of material) cannot readily be made subject to any general rule. It is, therefore, recommended that in such cases the number of places be settled by definite agreements between the persons involved.

8. **Comments.**—In making use of such limits, the engineer should hold in mind (1) the restrictions as to (*a*) controlled conditions, (*b*) approximate normality of universe, (*c*) randomness of sample; and (2) the fact that the variability under consideration relates to fluctuations around the level of measurement values, whatever that may be, quite regardless of whether or not the objective average, $\bar{X}'$, of the measurement values is widely displaced from the true value, $\bar{X}'_T$, of the thing measured, as a result of systematic or *constant* errors present throughout the measurements. For example, breaking strength values might center around a value of 575.0 lb. (the objective level $\bar{X}'$ of the measurement values) with a scatter of individual observations represented by the dotted distribution curve of Fig. 2, whereas the true average $\bar{X}'_T$ for the batch of wire under test is actually 610.0 lb.; the difference between 575.0 and 610.0 representing a constant or systematic error present in *all* the observations as a result, say, of an incorrect adjustment of the testing machine.

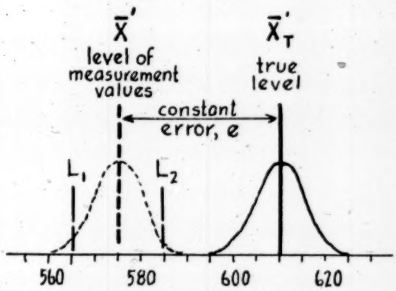

FIG. 2.—Showing How ± Limits (L_1 and L_2) are Unrelated to a Systematic or Constant Error.

The limits thus have meaning for series of like measurements, made under like conditions, *including* the same constant errors if any be present.

In the practical use of these limits, the engineer may not have assurance that conditions (*a*), (*b*), and (*c*) given in Section 4 are met, hence it is not advisable to lay great emphasis on the exact magnitudes of the chances given in Table II, but rather to consider them as orders of magnitude to be used as general guides.

SUPPLEMENT B (1935) TO A.S.T.M. MANUAL ON PRESENTATION OF DATA[1]

"CONTROL CHART" METHOD OF ANALYSIS AND PRESENTATION OF DATA

1. **Purpose.**—This Supplement[2] gives formulas and tables useful in applying the "control chart" method[3] of analysis and presentation of quality data obtained from several samples. This method provides a criterion for detecting lack of statistical control of quality, which is often used for determining when observed variations in quality are greater than should be left to chance.

2. **Terminology and Technical Background.**—Variation in quality from one unit of product to another is due to a large number of causes. Those which it is possible to identify are termed "assignable causes."

For a constant system of chance causes, the averages, $\bar{X}$, the standard deviations, σ, the values of fraction defective, p, or other functions of the observations of a series of samples will exhibit statistical stability of the kind that may be expected in random samples from homogeneous material. The criterion of the quality control chart is derived from laws of chance variations for such samples, and failure to satisfy this criterion is taken as evidence of the presence of an assignable cause of variation.

As applied by the manufacturer to inspection data, the control chart provides a basis for *action*. Continued use of the control chart and the elimination of assignable causes as their presence is disclosed by failures to meet its criterion tend to reduce variability and to stabilize quality at aimed-at levels. While the control chart method has been devised primarily for this purpose, it provides a simple technique and criterion that has been found practically useful in analyzing and interpreting other types of data.[1]

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[1] 1933 Manual on Presentation of Data, sponsored by Committee E-1 on Methods of Testing, *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 451 (1933); also published in pamphlet form.

[2] This Supplement is one of a series prepared by the Manual Committee of Technical Committee IX on Interpretation and Presentation of Data of Committee E-1 on Methods of Testing.

Personnel of Manual Committee, 1934–1935:

Messrs. H. F. Dodge, Chairman
W. C. Chancellor
J. T. MacKenzie
R. T. Webster

The nomenclature is the same as that used in the 1933 A.S.T.M. Manual on Presentation of Data.

The committee is indebted to Mr. H. G. Romig and Miss M. N. Torrey for assistance in preparation of numerical examples.

[3] As given by W. A. Shewhart, "Economic Control of Quality of Manufactured Product," Chapters XIX and XX, D. Van Nostrand Co., Inc., New York City (1931).

3. **Two Uses.**—The control chart method of analysis is used for the following two distinct purposes:

(*A*) *Control with Respect to a Given Standard*—to discover whether observed values of $\bar{X}$, σ, p, etc., for samples of n observations each, *differ from standard* values, $\bar{X}'$, σ', p', etc., by an amount greater than should be attributed to chance. The standard value may be one established by authority, such as a desired or aimed-at value designated by specification, or an economic standard level provided by experience. Control charts based on such standards are used particularly in inspection work to control processes and to maintain quality uniformly at the level desired.

(*B*) *Control—No Standard Given*—to discover whether observed values of $\bar{X}$, σ, p, etc., for several samples of n observations each, *vary among themselves* by an amount greater than should be attributed to chance. Control charts based entirely on the data from samples are used for detecting *lack of constancy* of the cause system.

4. **Breaking up Data into Rational Subgroups.**—One of the essential features of the method is what is referred to as breaking up the data into "rational subgroups"; that is, classifying the total set of test observations under consideration into subgroups or samples, *within* which variations may be considered to be due to non-assignable chance causes only, but *between* which there may be differences due to assignable causes whose presence is suspected or considered possible.

This part of the problem is obviously not statistical in character but depends on technical knowledge and familiarity with the conditions under which the material sampled was produced and the conditions under which the data were taken. By identifying each sample with a time or a source, specific causes of trouble may be more readily traced and corrective action taken, if advantageous and economical. Inspection and test records giving observations in the order in which they were taken, provide directly a basis for subgrouping with respect to time. This is commonly advantageous in manufacture where it is important, from the standpoint of quality, to maintain the production cause system constant with time.

5. **General Technique in Using Control Chart Method.**—The general technique[2] of the method is as follows:

Given a set of observations, to determine whether an assignable cause of variation is present:

(*a*) Divide the total number of observations in m rational subgroups (samples) having n_1, n_2, . . . n_m observations, respectively. Make subgroups of *equal size* if possible.

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[1] For example, in certain classes of engineering and research problems. The method is of course but one of the many statistical tools available.

[2] This embodies the procedure covered by "Criterion I," Shewhart, *loc. cit.*, Chapter XX.

(*b*) For each statistic ($\bar{X}$, σ, p, etc.) to be used, construct a control chart with control limits in the manner indicated in the subsequent sections.

(*c*) If one or more of the observed values of $\bar{X}$, σ, p, etc., for the m subgroups (samples) falls outside the control limits, take this fact as an indication of the presence of an assignable cause.

6. **Control Limits.**—In both uses indicated in Section 3, the control chart consists in symmetrical limits (control limits) placed above and below the expected value of $\bar{X}$, σ, p, etc. (central line) for samples of n observations each, under controlled conditions, which would be approached as a statistical limit as the number of such samples of size n is increased indefinitely, that is, the expected value of $\bar{X}$, σ, p, etc., for that sample size.

Control limits—for averages................(expected $\bar{X}$) $\pm 3\sigma_{\bar{X}}$
for standard deviations......(expected σ) $\pm 3\sigma_{\sigma}$
for ranges..................(expected R) $\pm 3\sigma_{R}$
for values of p.............(expected p) $\pm 3\sigma_{p}$

Figure 1 indicates the features of a control chart for averages.

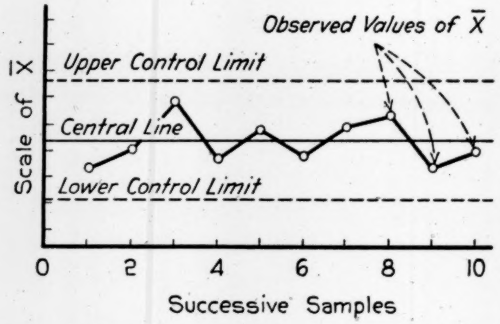

FIG. 1.—Essential Features of a Control Chart Presentation. Chart for Averages.

The choice of the factor 3 (a multiple of the standard deviation of $\bar{X}$, σ, p, etc.) in these limits is an economic choice based on experience, rather than on any exact value of probability.[1] It is one that has proven satisfactory for use in a criterion for *action*—for looking for assignable causes of variation.

CONTROL WITH RESPECT TO A GIVEN STANDARD

7. **Introduction.**—This part of the Appendix relates to the technique of analysis for control with respect to a given standard, as noted under (*A*) in Section 3. Here, standard values of $\bar{X}'$, σ', p', etc., are *given*, and are

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[1] See Shewhart, *loc. cit.*, pp. 276–277.

those corresponding to the given standard distribution. The expected values, used as central lines on the control charts are, therefore,

for averages. . . . . $\bar{X}'$,
for standard deviations. . . . . $c_2\sigma'$,
for ranges. . . . . $d_2\sigma'$, and
for values of p. . . . . p'

where factors c_2 and d_2 are given in Table I.[1]

TABLE I.—FACTORS FOR COMPUTING CONTROL CHART LINES—SMALL SAMPLES.

Number of Observations in Sample, n	Chart for Averages			Chart for Standard Deviations					Chart for Ranges				
	Factors for Control Limits			Factor for Central Line	Factors for Control Limits				Factor for Central Line	Factors for Control Limits			
	A	A_1	A_2	c_2	B_1	B_2	B_3	B_4	d_2	D_1	D_2	D_3	D_4
2.	2.121	3.759	1.880	0.5642	0	2.064	0	3.658	1.128	0	3.686	0	3.268
3.	1.732	2.394	1.023	0.7236	0	1.948	0	2.692	1.693	0	4.358	0	2.574
4.	1.500	1.880	0.729	0.7979	0	1.859	0	2.330	2.059	0	4.698	0	2.282
5.	1.342	1.596	0.577	0.8407	0	1.789	0	2.128	2.326	0	4.918	0	2.114
6.	1.225	1.410	0.483	0.8686	0.003	1.735	0.003	1.997	2.534	0	5.078	0	2.004
7.	1.134	1.277	0.419	0.8882	0.086	1.690	0.097	1.903	2.704	0.205	5.023	0.076	1.858
8.	1.061	1.175	0.373	0.9027	0.153	1.653	0.169	1.831	2.847	0.387	5.307	0.136	1.864
9.	1.000	1.094	0.337	0.9139	0.207	1.621	0.227	1.774	2.970	0.546	5.394	0.184	1.816
10.	0.949	1.028	0.308	0.9228	0.252	1.594	0.273	1.727	3.078	0.687	5.469	0.223	1.777
11.	0.905	0.973	0.285	0.9300	0.290	1.570	0.312	1.688	3.173	0.822	5.534	0.259	1.744
12.	0.866	0.925	0.266	0.9359	0.324	1.548	0.346	1.654	3.258	0.925	5.593	0.284	1.717
13.	0.832	0.884	0.249	0.9410	0.353	1.529	0.375	1.625	3.336	1.026	5.646	0.308	1.692
14.	0.802	0.848	0.235	0.9453	0.378	1.512	0.400	1.599	3.407	1.121	5.693	0.329	1.671
15.	0.775	0.817	0.223	0.9490	0.401	1.497	0.423	1.577	3.472	1.207	5.737	0.348	1.652
16.	0.750	0.788	. . . . .	0.9523	0.422	1.483	0.443	1.557	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
17.	0.728	0.762	. . . . .	0.9551	0.441	1.470	0.462	1.539	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
18.	0.707	0.738	. . . . .	0.9577	0.458	1.458	0.478	1.522	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
19.	0.688	0.717	. . . . .	0.9599	0.473	1.447	0.493	1.507	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
20.	0.671	0.698	. . . . .	0.9619	0.488	1.436	0.507	1.493	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
21.	0.655	0.680	. . . . .	0.9638	0.501	1.427	0.520	1.481	. . . .	. . . . .	. . . . .	. . . . .	. . . . .
22.	0.639	0.662	. . . . .	0.9655	0.513	1.418	0.531	1.469	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
23.	0.626	0.647	. . . . .	0.9670	0.525	1.409	0.543	1.457	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
24.	0.612	0.632	. . . . .	0.9684	0.535	1.401	0.552	1.447	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
25.	0.600	0.619	. . . . .	0.9697	0.545	1.394	0.562	1.438	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .

CENTRAL LINES AND CONTROL LIMITS.

(1) Control with Respect to a Given Standard ($\bar{X}'$, σ' given)

	CENTRAL LINE	CONTROL LIMITS
Averages.	$\bar{X}'$	$\bar{X}' \pm A\sigma'$
Standard deviations.	$c_2\sigma'$	$B_1\sigma'$ and $B_2\sigma'$
Ranges.	$d_2\sigma'$	$D_1\sigma'$ and $D_2\sigma'$

(2) Control—No Standard Given ($\bar{X}'$, σ', not given)

	CENTRAL LINE	CONTROL LIMITS
Averages using σ.	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm A_1\bar{\sigma}$ ($\bar{\sigma}$ as given by Eq. 13)
Averages using R.	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm A_2\bar{R}$ ($\bar{R}$ as given by Eq. 16)
Standard deviations	$\bar{\sigma}$	$B_3\bar{\sigma}$ and $B_4\bar{\sigma}$ ($\bar{\sigma}$ as given by Eq. 13)
Ranges.	$\bar{R}$	$D_3\bar{R}$ and $D_4\bar{R}$ ($\bar{R}$ as given by Eq. 16)

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[1] Table I gives many of the factors here proposed for use in computing control chart lines. The convenient tabular arrangement of this table corresponds closely to that used in E. S. Pearson's "Report on the Application of Statistical Methods to Industrial Standardization and Quality Control," British Standards Inst.

8. **Control Charts for Averages, $\bar{X}$, and for Standard Deviations, σ.**

For samples of size n,

CONTROL CHART LINES

	Central Line	Control Limits	
		Values Using Factors in Table I	Equation
For averages, $\bar{X}$............	$\bar{X}'$	$\bar{X}' \pm A\sigma'$	$\bar{X}' \pm 3\frac{\sigma'}{\sqrt{n}}$............(1)
For standard deviations, σ....	$c_2\sigma'$	$B_1\sigma'$ and $B_2\sigma'$	$c_2\sigma' \pm 3\frac{\sigma'}{\sqrt{2n}}$............(2)

For samples of n greater than 25, consider $c_2 = 1$.

For samples of $n = 25$ or less, use Table I for factors A, B_1 and B_2.

9. **Control Chart for Ranges, R.**—The range, R, of a sample is the difference between the largest observation and the smallest observation.

For samples of size n,

CONTROL CHART LINES

	Central Line	Control Limits	
		Values Using Factors in Table I	Equation
For range, R..............	$d_2\sigma'$	$D_1\sigma'$ and $D_2\sigma'$	$d_2\sigma' \pm 3\sigma_R$............(3)

For samples of $n = 15$ or less, use Table I for factors d_2, D_1 and D_2.

Values of σ_R are given by Tippett.[1]

Comments on Use of Control Chart for Ranges.—Because of ease of computation, the control chart for range, R, is frequently used as an economical substitute for the control chart for standard deviaton, σ, more particularly in routine inspection work. It is not recommended as a substitute, however, for samples of more than 10 observations, since the range becomes rapidly less efficient than the standard deviation as a detector of assignable causes as n increases beyond this value.

10. **Control Chart for Values of p.**—The function p is widely used in inspection to represent the "fraction defective," that is, the fraction of the total number of units in a sample that fails to conform with a requirement for a unit. A single instance of a quality irregularity, such as a failure to conform with a requirement for a unit, will be termed a "defect."

This measure of quality (fraction defective p) is particularly useful in inspection and testing, for characteristics that can be measured only on a go no-go basis (method of attributes) and is widely used for variable characteristics even where measured values are obtained (method of variables). The function, p, may also be used for fraction of total number of observations falling above or below *any* chosen value of X (or within or without any two chosen values of X), for a variable characteristic. Ordinarily, the control chart for p is most useful when samples are large, say when n is greater than 50 to 100; more specifically when the expected number of items (defects, or other occurrences of interest) per sample is four or more (expected pn = 4 or more).

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[1] L. H. C. Tippett, "On the Extreme Individuals and the Range of Samples Taken from a Normal Population," *Biometrika*, Vol. XVII, Parts III and IV, December, 1925, pp. 364–387.

For samples of size n,

CONTROL CHART LINES

	CENTRAL LINE	CONTROL LIMITS	
For values of p..................	p'	$p' \pm 3\sqrt{\frac{p'(1-p')}{n}}$........	(4)

11. **Control Chart for Number of "Defects," pn.**—See explanation of "defect" in Section 10. This chart is the equivalent of the control chart for p, for which it is a convenient practical substitute particularly when all samples have the same size, n. It makes direct use of the number of defects, pn, in a sample (pn = fraction defective times sample size).

For samples of size n,

CONTROL CHART LINES

	CENTRAL LINE	CONTROL LIMITS	
For values of pn................	$p'n$	$p'n \pm 3\sqrt{p'n\,(1-p')}$........	(5)

When p' is small, say less than 0.05, $(1 - p')$ may be considered as equal to unity for most practical purposes, which gives the simple equation:

$$\text{Control limits} = p'n \pm 3\sqrt{p'n} \qquad (6)$$

CONTROL—NO STANDARD GIVEN

12. **Introduction.**—This part of the Supplement relates to the technique of analysis for control when no standard is given, as noted under (*B*) in Section 3. Here standard values of $\bar{X}'$, σ', p', etc., are *not given*, hence values derived from the numerical observations are used for the purpose of analysis. The values used as central lines are indicated in the following sections for various conditions.

13. **Control Charts for Averages and for Standard Deviations—Large Samples.**—This section assumes that a set of observed values of a variable X is divisible into m rational subgroups (samples) of *more than 25* observations each, having n_1, n_2, . . . n_m observations, respectively.

(*a*) *Samples Approximately Equal in Size:*

CONTROL CHART LINES

	Central Line	Control Limits	
For averages, $\bar{X}$	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm 3 \dfrac{\sigma}{\sqrt{\bar{n}}}$	(7)
For standard deviations, σ	σ	$\sigma \pm 3 \dfrac{\sigma}{\sqrt{2\bar{n}}}$	(8)

where $\bar{\bar{X}}$ = the grand average of the observed values of X for *all* samples,

$$\sigma = \sqrt{\frac{n_1\sigma_1^2 + n_2\sigma_2^2 + \ldots\ldots + n_m\sigma_m^2}{n_1 + n_2 + \ldots\ldots + n_m}} \qquad (9)$$

$$\bar{n} = \frac{n_1 + n_2 + \ldots\ldots + n_m}{m} = \text{average number of observations per sample.}$$

(*b*) *Samples Widely Different in Size.*—Same as in Paragraph (*a*), except compute control limits for each sample separately, using the individual sample size, n, in the equation for control limits.

(*c*) *Samples of Equal Size.*—Same as in Paragraph (*a*), except

$$\sigma = \bar{\sigma} = \frac{\sigma_1 + \sigma_2 + \ldots\ldots + \sigma_m}{m} \qquad (10)$$

$\bar{n} = n$ = number of observations in each sample.

14. **Control Charts for Averages and for Standard Deviations—Small Samples of Equal Size.**—This section assumes that a set of observed values of a variable X is divisible into m rational subgroups (samples) of *equal size*, each subgroup containing n = *25 or less* observed values.

CONTROL CHART LINES

	Central Line	Control Limits		
		Values Using Factors in Table I	Equation	
For averages, $\bar{X}$	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm A_1\bar{\sigma}$	$\bar{\bar{X}} \pm 3 \dfrac{\bar{\sigma}}{c_2\sqrt{n}}$	(11)
For standard deviations, σ	$\bar{\sigma}$	$B_3\bar{\sigma}$ and $B_4\bar{\sigma}$	$\bar{\sigma} \pm 3 \dfrac{\bar{\sigma}}{c_2\sqrt{2n}}$	(12)

where X = the grand average of observed values of X for *all* samples,

$$\sigma = \frac{\sigma_1 + \sigma_2 + \ldots\ldots \sigma_m}{m} \qquad (13)$$

where σ_1, σ_2, etc., refer to the observed standard deviations for the first second, etc., samples.

and factors c_2, A_1, B_3 and B_4 are given in Table I.

For *small samples of unequal size*, no general rule may be given in view of certain theoretical difficulties. The following working rule is however generally satisfactory. Use Eqs. 1 and 2 (or factors) given in Section 8, substituting for σ' in Section 8 the *average* value of $\frac{\text{observed } \sigma}{c_2}$ for the individual samples. As shown in example B5 of Section 19, the computation can be simplified by combining in separate groups all samples having the same sample size, n. Control limits may then be determined separately as in Section 8, for each sample size, n. These difficulties can be avoided, if in planning for the collection of data, the samples are made of equal size.

15. **Control Charts for Averages, $\bar{X}$, and for Ranges, R,—Equal Samples of $n = 10$ or Less.**—This section assumes that a set of observed values of a variable X is divisible into m rational subgroups (samples) of *equal size*, each subgroup containing n = *10 or less* observed values.

Where *economy of effort* is important, this method may be used if it is desired to construct a control chart for averages only, or control charts for averages and ranges instead of for averages and standard deviations as in Section 14.

See comments in Section 9 on the use of control charts for ranges.

CONTROL CHART LINES

	Central Line	Control Limits	
		Values Using Factors in Table I	Equation
For averages, $\bar{X}$	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm A_2\bar{R}$	$\bar{\bar{X}} \pm 3\frac{\bar{R}}{d_2\sqrt{n}}$ . . . . (14)
For ranges, R	$\bar{R}$	$D_3\bar{R}$ and $D_4\bar{R}$	$\bar{R} \pm 3\sigma_R$ . . . . (15)

where $\bar{\bar{X}}$ = the grand average of observed values of X for *all* samples,

$\bar{R}$ = the average value of range R for the m individual samples,

$$= \frac{R_1 + R_2 + \ldots\ldots + R_m}{m} \qquad (16)$$

d_2, A_2, D_3 and D_4 are given in Table I, and σ_R may be found in tables by Tippett[1] by taking $\bar{R}/d_2$ as the standard deviation of the universe sampled.

For *samples of unequal size*, no general rule can be given. The following working rule is however generally satisfactory. Use Eqs. 1 and 3 (or factors) in Sections 8 and 9, substituting for σ' in Sections 8 and 9 the *average* value of the ratio $\frac{\text{observed } R}{d_2}$ for the individual samples. As shown in example B6 of Section 19, the computation can be simplified by combining in separate groups all samples having the same sample size, n. Control limits may then be determined separately as in Sections 8 and 9 for each sample size, n. These difficulties can be avoided, however, if in planning for the collection of data the samples are made of equal size.

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[1] *Loc. cit.*

16. **Control Chart for Values of p.**—This section assumes that the set of test records is divisible into m rational subgroups (samples) representing $n_1, n_2, \ldots n_m$ units, respectively. See Section 10 for brief discussion of uses of p as a measure of quality. In this section, p will for convenience be referred to as the "fraction defective."

(*a*) *Samples Approximately Equal in Size:*

CONTROL CHART LINES

	CENTRAL LINE	CONTROL LIMITS	
For values of p	$\bar{p}$	$\bar{p} \pm 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{\bar{n}}}$	(17)

$$\text{where } \bar{p} = \frac{\text{total number of defects in all samples}}{\text{total number of units in all samples}} \qquad (18)$$

= fraction defective in the complete set of records

$\bar{n}$ = average sample size for the m samples.

If the computed value of the lower control limit is negative, call it 0.

(*b*) *Samples Widely Different in Size.*—Same as in Paragraph (*a*), except compute control limits for each sample separately, using the individual sample size, n, in Eq. 17.

(*c*) *Samples of Equal Size.*—Same as in Paragraph (*a*), except

$\bar{n} = n$ = number of units in each sample.

17. **Control Chart for Number of "Defects," pn.**—See explanation of "defect" in Section 10. This chart is the equivalent of the control chart for p, for which it is a convenient practical substitute when all samples have the same size, n.

For samples of size n,

CONTROL CHART LINES

	CENTRAL LINE	CONTROL LIMITS	
For values of pn	$\bar{p}n$	$\bar{p}n \pm 3\sqrt{\bar{p}n\,(1-\bar{p})}$	(19)

$$\text{where } \bar{p}n = \frac{\text{total number of defects in all samples}}{\text{number of samples}} \qquad (20)$$

= the *average* number of defects in the m individual samples

$\bar{p}$ = the value given by Eq. 18.

When $\bar{p}$ is small, say less than 0.05, $(1 - \bar{p})$ may be considered as equal to unity for most practical purposes, which gives the simple equation,

Control limits $= \bar{p}n \pm 3\sqrt{\bar{p}n}$

= (average number of defects) ± $3\sqrt{\text{(average number of defects)}}$ where "average number of defects" means *average number* in the equal samples.

This is an application of the Poisson Exponential. As illustrated by example B9 of Section 19, this chart is a particularly convenient one to use where $\bar{p}$ and n are indeterminate, as for certain quality characteristics of finishes, textiles, materials, etc., which are continuous or extensive in respect to the feature of interest (such as physical defects, finish irregularities, flaws, etc.). Theoretically the requirements for its use are that $\bar{p}$ shall be very small, n very large, and $\bar{p}n$ (the average number of occurrences per unit sample) finite.

EXAMPLES

18. Control with Respect to a Given Standard.

Example A1—Control Charts for $\bar{X}$ and σ, Sample Sizes Equal and Large (Section 8).—A manufacturer attempted to maintain an aimed-at distribution of quality for a certain operating characteristic. The objective standard distribution which served as a target was defined by standard values $\bar{X}' = 35.00$ lb. and $\sigma' = 4.20$ lb. Table II gives observed values of $\bar{X}$ and σ for daily samples of $n = 50$ observations each for ten consecutive days. Figure 2 gives control charts for $\bar{X}$ and σ.

TABLE II.—OPERATING CHARACTERISTIC, DAILY CONTROL DATA.

SAMPLE	SAMPLE SIZE, n	AVERAGE, $\bar{X}$	STANDARD DEVIATION, σ
No. 1	50	35.7	5.35
No. 2	50	34.6	5.03
No. 3	50	32.6	3.43
No. 4	50	35.3	4.55
No. 5	50	33.4	4.10
No. 6	50	35.2	4.30
No. 7	50	33.3	5.18
No. 8	50	33.9	5.30
No. 9	50	32.3	3.09
No. 10	50	33.7	3.67

Central Lines

For $\bar{X}$: $\bar{X}' = 35.00$.

For σ: $\sigma' = 4.20$.

Control Limits

For $\bar{X}$: $\bar{X}' \pm 3\dfrac{\sigma'}{\sqrt{n}} = 35.00 \pm 1.78$,

33.22 and 36.78.

For σ: $\sigma' \pm 3\dfrac{\sigma'}{\sqrt{2n}} = 4.20 \pm 1.260$,

2.940 and 5.460.

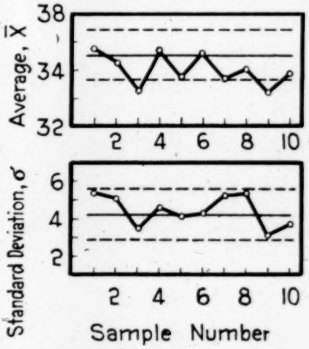

FIG. 2.—Control Charts for $\bar{X}$ and σ.
Large samples, $\bar{X}'$, σ' given.

RESULTS: Lack of control at standard level indicated on third and ninth days.

Example A2—Control Charts for $\bar{X}$ and R (Sections 8 and 9).—Same problem as in example A1 where $\bar{X}' = 35.00$ lb. and $\sigma' = 4.20$ lb. The manufacturer wished to control variations in quality from lot to lot by taking a small sample from each lot. Table III gives observed values of $\bar{X}$ and R for samples of $n = 9$ each, selected from ten consecutive lots. Since the sample size n is less than 10 he elected to use control charts for $\bar{X}$ and R rather than for $\bar{X}$ and σ. Figure 3 gives the control charts for $\bar{X}$ and R.

TABLE III.—OPERATING CHARACTERISTIC, LOT BY LOT CONTROL DATA.

LOT	SAMPLE SIZE, n	AVERAGE, $\bar{X}$	RANGE, R
No. 1	9	37.6	9.5
No. 2	9	31.4	6.0
No. 3	9	34.7	13.5
No. 4	9	35.8	12.0
No. 5	9	38.5	21.0
No. 6	9	34.2	17.5
No. 7	9	36.1	15.5
No. 8	9	32.3	18.0
No. 9	9	35.0	12.5
No. 10	9	33.9	14.0

Central Lines

For $\bar{X}$: $\bar{X}' = 35.00$.
For R: $d_2\sigma' = 2.97\,(4.20) = 12.47$.

Control Limits

For $\bar{X}$: $\bar{X}' \pm A\sigma' = 35.00 \pm (1.000)(4.20)$,
30.80 and 39.20.

For R: $D_1\sigma'$ and $D_2\sigma'$,
$(0.546)(4.20)$ and $(5.394)(4.20)$,
2.29 and 22.65.

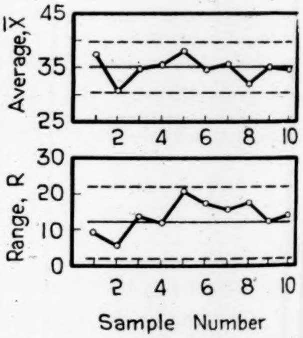

FIG. 3.—Control Charts for $\bar{X}$ and R.
Small samples. $\bar{X}'$, σ' given.

RESULTS: Since no points fell outside the control limits on either chart, no corrective action appeared necessary.

Example A3—Control Charts for Fraction Defective p (Section 10).—The manufacturer wished to control quality of an adjustment characteristic of a type of electrical apparatus at a level such that the fraction defective $p' = 0.0020$ (2 defective units per thousand). Table IV gives observed values of "number of defects" for this item found in samples drawn from successive lots. Sample sizes vary considerably from lot to lot and, hence, control limits are computed for each sample. Equivalent control limits for "number of defects," pn, are shown in the table. In this way, the original records showing "number of defects" may be compared directly with control limits for pn and it would not be necessary to compute the value of p in each instance. Figure 4 shows the control chart for p.

TABLE IV.—ADJUSTMENT IRREGULARITIES, ELECTRICAL APPARATUS.

Lot	Sample Size, n	Number of Defects	Fraction Defective, p	Upper Control Limit for pn	Upper Control Limit for p
No. 1	600	2	0.0033	4.4	0.0074
No. 2	1300	2	0.0015	7.3	0.0056
No. 3	2000	1	0.0005	10.0	0.0050
No. 4	2500	1	0.0004	11.7	0.0047
No. 5	1550	5	0.0032	8.2	0.0053
No. 6	2000	2	0.0010	10.0	0.0050
No. 7	1550	0	0	8.2	0.0053
No. 8	780	3	0.0038	5.3	0.0068
No. 9	260	0	0	2.7	0.0104
No. 10	2000	15	0.0075	10.0	0.0050
No. 11	1550	7	0.0045	8.2	0.0053
No. 12	950	2	0.0021	6.2	0.0065
No. 13	950	5	0.0053	6.2	0.0065
No. 14	950	2	0.0021	6.2	0.0065
No. 15	35	0	0	0.9	0.0248
No. 16	330	3	0.0091	3.1	0.0095
No. 17	200	0	0	2.3	0.0116
No. 18	600	4	0.0067	4.4	0.0074
No. 19	1300	8	0.0062	7.3	0.0056
No. 20	780	4	0.0051	5.3	0.0068

Central Line

$$p' = 0.0020$$

Control Limits

$$p' \pm 3\sqrt{\frac{p'(1-p')}{n}}.$$

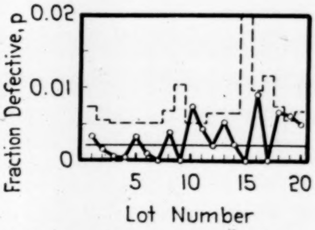

FIG. 4.—Control Chart for p.
p' given.

Upper control limits given in last column of Table IV. Computed values of lower control limit are negative for all n sizes, hence are all taken as equal to 0.

RESULTS: Lack of control and need for corrective action indicated by lots Nos. 10 and 19.

19. Control—No Standard Given.

Example B1—Control Charts for $\bar{X}$ and σ, Equal Large Samples (Section 13).—Same data as in example A1 and Table II. Although in example A1, quality did not appear to be controlled at the standard level, the manufacturer wished to determine if his product were controlled at *some* level other than the standard level. In this case, central lines and control limits are based solely on the data. Figure 5 gives control charts for $\bar{X}$ and σ.

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 34.00$.
For σ: $\bar{\sigma} = 4.40$.

Control Limits

For $\bar{X}$: $\bar{\bar{X}} \pm 3 \dfrac{\bar{\sigma}}{\sqrt{n}} = 34.00 \pm 1.87$,
32.13 and 35.87.

For σ: $\bar{\sigma} \pm 3 \dfrac{\bar{\sigma}}{\sqrt{2n}} = 4.40 \pm 1.320$,
3.080 and 5.720.

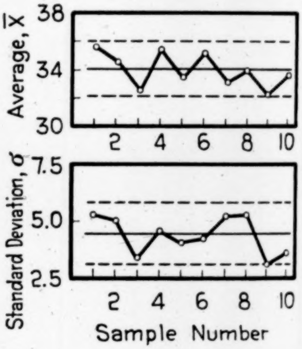

FIG. 5.—Control Charts for $\bar{X}$ and σ.
Large equal samples, no standard given.

RESULTS: Charts do not indicate lack of control, but comparing these results with those obtained in Fig. 2 (example A1), it would appear necessary for the manufacturer to make such adjustment in his process as to raise the control level for $\bar{X}$ up to the desired standard value.

Example B2—Control Charts for $\bar{X}$ and σ, Unequal Large Samples (Section 13(b)). —To determine whether there existed any assignable causes of variation in quality for an important operating characteristic of a given product, the inspection results given in Table V were obtained from ten shipments of a product. The samples from the ten shipments are unequal in size; hence, control limits are computed separately for each sample size. Figure 6 gives the control charts for $\bar{X}$ and σ.

TABLE V.—OPERATING CHARACTERISTIC, MECHANICAL PART.

SHIPMENT	SAMPLE SIZE, n	AVERAGE, $\bar{X}$	STANDARD DEVIATION, σ	VARIANCE, σ^2
No. 1	50	55.7	4.35	18.9225
No. 2	50	54.6	4.03	16.2409
No. 3	100	52.6	2.43	5.9049
No. 4	25	55.0	3.56	12.6736
No. 5	25	53.4	3.10	9.6100
No. 6	50	55.2	3.30	10.8900
No. 7	100	53.3	4.18	17.4724
No. 8	50	52.3	4.30	18.4900
No. 9	50	53.7	2.09	4.3681
No. 10	50	54.3	2.67	7.1289
	$\bar{n} = 55$			
	Weighted average =	53.80		12.1761

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 53.80$.

For σ: $\bar{\sigma} = \sqrt{12.1761} = 3.49$.

Control Limits

For $\bar{X}$: $\bar{\bar{X}} \pm 3\dfrac{\bar{\sigma}}{\sqrt{n}} = 53.80 \pm \dfrac{10.47}{\sqrt{n}}$,

$n =$ 25: 51.71 and 55.89,

$n =$ 50: 52.32 and 55.28,

$n =$ 100: 52.75 and 54.85.

For σ: $\bar{\sigma} \pm 3\dfrac{\bar{\sigma}}{\sqrt{2n}} = 3.49 \pm \dfrac{10.47}{\sqrt{2n}}$,

$n =$ 25: 2.01 and 4.97,

$n =$ 50: 2.44 and 4.54,

$n =$ 100: 2.75 and 4.23.

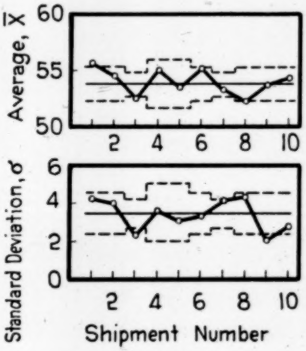

FIG. 6.—Control Charts for $\bar{X}$ and σ.
Large unequal samples, no standard given.

NOTE.—In this example the average sample size, $\bar{n}$, is not used since the difference between n sizes is too great (see Section 13 (*b*)).

RESULTS: Investigation was made of causes of the high average in the first shipment and the low averages in the third and eighth shipments. The standard deviation was favorably low in the third and ninth shipments.

Example B3—Control Charts for $\bar{X}$ and σ, Equal Small Samples (Section 14).—Table VI gives breaking strength results on 10 lots of steel wire strand. A sample of $n = 4$ test specimens was taken per lot. Figure 7 shows control charts for $\bar{X}$ and σ.

TABLE VI.—BREAKING STRENGTH, STEEL WIRE STRAND.

Lot	Test Values				Average, $\bar{X}$	Standard Deviation, σ	Range, R
	X_1	X_2	X_3	X_4			
No. 1	7490	7535	7455	7480	7490.0	28.94	80
No. 2	6550	6495	6525	6465	6508.75	31.90	85
No. 3	6995	6995	6970	6880	6960.0	47.30	115
No. 4	7045	7060	7095	7035	7058.75	22.74	60
No. 5	6715	6740	6780	6720	6738.75	25.59	65
No. 6	6585	6630	6675	6645	6633.75	32.48	90
No. 7	6600	6590	6610	6650	6612.5	22.78	60
No. 8	6665	6670	6630	6660	6656.25	15.56	40
No. 9	6440	6425	6460	6470	6448.75	17.46	45
No. 10	6660	6630	6605	6625	6630.0	19.69	55
Average					6773.75	26.44	69.5

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 6773.75$.
For σ: $\bar{\sigma} = 26.44$.

Control Limits

For $\bar{X}$: $\bar{\bar{X}} \pm A_1\bar{\sigma} = 6773.75 \pm 1.880(26.44)$,
6724.04 and 6823.46.
For σ: $B_3\bar{\sigma}$ and $B_4\bar{\sigma} = (0)(26.44)$ and
(2.330)(26.44), 0 and 61.61.

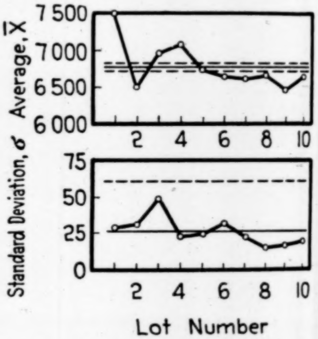

FIG. 7.—Control Charts for $\bar{X}$ and σ.
Small equal samples, no standard given.

RESULTS: Charts indicate the presence of assignable causes of variation in average breaking strength, $\bar{X}$, from lot to lot.

Example B4—Control Charts for $\bar{X}$ and R, Equal Small Samples (Section 15).—Same data as in example B3, Table VI. Use is made here of control charts for averages and ranges rather than for averages and standard deviations. Figure 8 shows control charts for $\bar{X}$ and R.

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 6773.75$.
For R: $\bar{R} = 69.5$.

Control Limits

For $\bar{X}$: $\bar{\bar{X}} \pm A_2\bar{R} = 6773.75 \pm (0.729)(69.5)$,
6723.08 and 6824.42.
For R: $D_3\bar{R}$ and $D_4\bar{R} = (0)(69.5)$ and
(2.282)(69.5), 0 and 158.60.

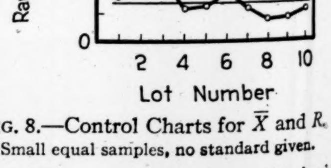

FIG. 8.—Control Charts for $\bar{X}$ and R.
Small equal samples, no standard given.

RESULTS: The results are practically identical in all respects with those obtained by using average and standard deviation, Fig. 7.

Example B5—Control Charts for $\bar{X}$ and σ, Small Unequal Samples (Section 14).—Table VII gives interlaboratory calibration check data on 21 horizontal tension testing machines. The data represent tests on No. 16 wire. The procedure is similar to that given in example B3 but indicates a suggested method of computation when samples are not equal in size. Figure 9 gives control charts for $\bar{X}$ and σ

TABLE VII.—INTERLABORATORY CALIBRATION, HORIZONTAL TENSION TESTING MACHINES.

Machine	Number of Tests	Test Value					Average, $\bar{X}$	Standard Deviation, σ		Range, R	
		1	2	3	4	5		$n = 4$	$n = 5$	$n = 4$	$n = 5$
No. 1	5	73	73	73	75	75	73.8	....	0.98	....	2
No. 2	5	70	71	71	71	72	71.0	....	0.63	....	2
No. 3	5	74	74	74	74	75	74.2	....	0.40	....	1
No. 4	5	70	70	70	72	73	71.0	....	1.26	....	3
No. 5	5	70	70	70	70	70	70.0	....	0	....	0
No. 6	5	65	65	66	69	70	67.0	....	2.10	....	5
No. 7	4	72	72	74	76	—	73.5	1.66	....	4	....
No. 8	5	69	70	71	73	73	71.2	....	1.60	....	4
No. 9	5	71	71	71	71	72	71.2	....	0.40	....	1
No. 10	5	71	71	71	71	72	71.2	....	0.40	....	1
No. 11	5	71	71	72	72	72	71.6	....	0.49	....	1
No. 12	5	70	71	71	72	72	71.2	....	0.75	....	2
No. 13	5	73	74	74	75	75	74.2	....	0.75	....	2
No. 14	5	74	74	75	75	75	74.6	....	0.49	....	1
No. 15	5	72	72	72	73	73	72.4	....	0.49	....	1
No. 16	4	75	75	75	76	—	75.3	0.19	....	1	....
No. 17	5	68	69	69	69	70	69.0	....	0.63	....	2
No. 18	5	71	71	72	72	73	71.8	....	0.75	....	2
No. 19	5	72	73	73	73	73	72.8	....	0.40	....	1
No. 20	5	68	69	70	71	71	69.8	....	1.17	....	3
No. 21	5	69	69	69	69	69	69.0	....	0	....	0
Total	103							1.85	13.69	5	34
Average	$\bar{n}=4.9$	Weighted average $\bar{\bar{X}} = 71.65$									

$$\sigma' = \frac{1}{21}\left(\frac{1.85}{0.7979} + \frac{13.69}{0.8407}\right) = 0.887$$

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 71.65$.

For σ: $n = 4$, $\bar{\sigma} = c_2\sigma' = (0.7979)(0.887) = 0.708$.

$n = 5$, $\bar{\sigma} = c_2\sigma' = (0.8407)(0.887) = 0.746$.

Control Limits

For $\bar{X}$: $n = 4$,

$\bar{\bar{X}} \pm A_1\bar{\sigma} = 71.65 \pm (1.880)(0.708)$, 70.32 and 72.98.

$n = 5$,

$\bar{\bar{X}} \pm A_1\bar{\sigma} = 71.65 \pm (1.596)(0.746)$, 70.46 and 72.84.

For σ: $n = 4$, $B_3\bar{\sigma}$ and $B_4\bar{\sigma}$, (0)(0.708) and (2.330)(0.708), 0 and 1.650.

$n = 5$, $B_3\bar{\sigma}$ and $B_4\bar{\sigma}$, (0)(0.746) and (2.128)(0.746), 0 and 1.587.

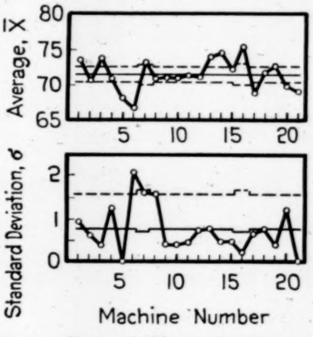

FIG. 9.—Control Charts for $\bar{X}$ and σ.
Small unequal samples, no standard given.

RESULTS: Calibration levels of machines were not closely controlled at a common level; the averages of six machines are above and the averages of five machines are below control limits. The variability *within* machines appeared fairly well controlled since only two machines, No. 6 and No. 8, have standard deviations outside control limits.

Example B6—Control Charts for $\bar{X}$ and R, Small Unequal Samples (Section 15).—Same data as in example B5, Table VII. In the analysis and control charts, the range is used instead of the standard deviation. The procedure is similar to that given in example B4 but indicates a suggested method of computation when samples are not equal in size. Figure 10 gives control charts for $\bar{X}$ and R.

$$\sigma' = \frac{1}{21}\left(\frac{5}{2.059} + \frac{34}{2.326}\right) = 0.812$$

Central Lines

For $\bar{X}$: $\bar{\bar{X}} = 71.65$.

For R: $n = 4, \bar{R} = d_2\sigma' = (2.059)(0.812) = 1.67$.

$n = 5, \bar{R} = d_2\sigma' = (2.326)(0.812) = 1.89$.

Control Limits

For $\bar{X}$: $n = 4$,

$\bar{\bar{X}} \pm A_2\bar{R} = 71.65 \pm (0.729)(1.67)$, 70.43 and 72.87.

$n = 5$,

$\bar{\bar{X}} \pm A_2\bar{R} = 71.65 \pm (0.577)(1.89)$, 70.56 and 72.74.

For R: $n = 4$, $D_3\bar{R}$ and $D_4\bar{R}$, (0)(1.67) and (2.282)(1.67), 0 and 3.81.

$n = 5$, $D_3\bar{R}$ and $D_4\bar{R}$, (0)(1.89) and (2.114)(1.89), 0 and 4.00.

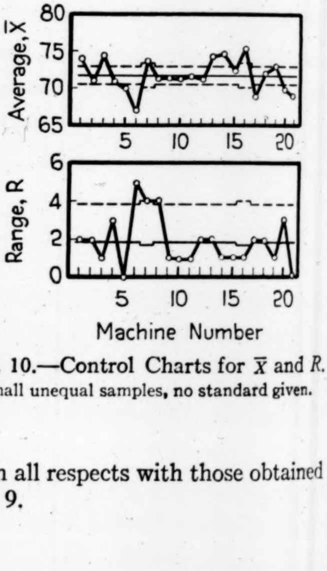

FIG. 10.—Control Charts for $\bar{X}$ and R.
Small unequal samples, no standard given.

RESULTS: The results are practically identical in all respects with those obtained by using the average and standard deviation, Figure 9.

Example B7—Control Chart for p (Section 16).—Table VIII gives inspection results for surface defects on 31 lots of a certain type of galvanized hardware. The quantity of hardware per lot varied considerably and corresponding variations in sample sizes were introduced. For purposes of control analysis here, the samples are considered as approximately equal in size and accordingly the method given in Section 16(*a*) is used. The control limits may therefore be based on the average sample size. Figure 11 gives the control chart for fraction defective, p. In practice, results are commonly expressed in "per cent defective," using scale values of 100 times p.

TABLE VIII.—SURFACE DEFECTS, GALVANIZED HARDWARE.

LOT	SAMPLE SIZE, n	NUMBER OF DEFECTS, pn	FRACTION DEFECTIVE
No. 1	580	9	0.0155
No. 2	550	7	0.0127
No. 3	580	3	0.0052
No. 4	640	9	0.0141
No. 5	760	11	0.0145
No. 6	760	12	0.0158
No. 7	510	9	0.0176
No. 8	550	10	0.0182
No. 9	640	10	0.0156
No. 10	640	10	0.0156
No. 11	640	8	0.0125
No. 12	640	10	0.0156
No. 13	580	7	0.0121
No. 14	580	9	0.0155
No. 15	550	5	0.0091
No. 16	430	5	0.0116
No. 17	640	3	0.0047
No. 18	580	4	0.0069
No. 19	510	6	0.0118
No. 20	580	8	0.0138
No. 21	600	8	0.0133
No. 22	640	12	0.0188
No. 23	640	9	0.0141
No. 24	580	8	0.0138
No. 25	580	8	0.0138
No. 26	510	4	0.0078
No. 27	640	6	0.0094
No. 28	550	8	0.0145
No. 29	550	8	0.0145
No. 30	430	3	0.0070
No. 31	430	6	0.0140
Total	18 090	235	

$$\bar{n} = \frac{18\,090}{31} = 584$$

$$\bar{p} = \frac{235}{18\,090} = 0.0130$$

Central Line for p

$$\bar{p} = 0.0130.$$

Control Limits for p

$$\bar{p} \pm 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.0130 \pm 0.0141,$$

$$0 \text{ and } 0.0271.$$

Correspondingly the control chart lines for pn are:

Central Line for pn

$$\bar{p}n = \frac{235}{31} = 7.59.$$

Control Limits for pn

$$\bar{p}n \pm 3\sqrt{\bar{p}n(1-\bar{p})} = 7.59 \pm 8.21,$$

$$0 \text{ and } 15.80.$$

RESULTS: No evidence of lack of control.

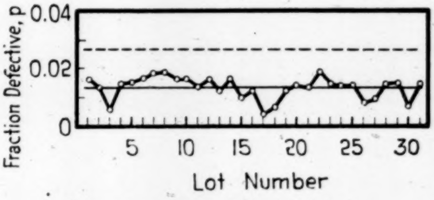

FIG. 11.—Control Chart for p.
No standard given.

Example B8—Control Chart for pn, (Section 17).—Table IX gives the number of defects found in inspecting a series of 15 consecutive lots of galvanized washers for finish defects such as exposed steel, rough galvanizing. The lots were of almost the same size and a constant sample size, $n = 400$ was used. Figure 12 gives the control chart for pn.

TABLE IX.—FINISH DEFECTS, GALVANIZED WASHERS.

LOT	SAMPLE SIZE, n	NUMBER OF DEFECTS, pn
No. 1	400	1
No. 2	400	3
No. 3	400	0
No. 4	400	7
No. 5	400	2
No. 6	400	0
No. 7	400	1
No. 8	400	0
No. 9	400	8
No. 10	400	5
No. 11	400	2
No. 12	400	0
No. 13	400	1
No. 14	400	0
No. 15	400	3
Total	6000	33

Central Line

$$\overline{pn} = \frac{33}{15} = 2.20.$$

Control Limits

$$\overline{pn} \pm 3\sqrt{\overline{pn}} = 2.2 \pm 4.4,$$

0 and 6.6.

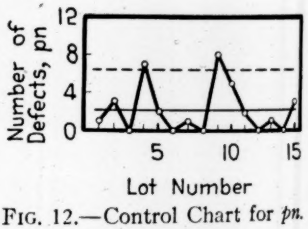

FIG. 12.—Control Chart for pn.
No standard given.

RESULTS: Lack of control of quality is indicated; points for lots Nos. 4 and 9 are outside control limits.

Example B9—Control Chart for pn, p and n Indeterminate (Section 17).—Table X gives the results of continuous testing of a certain type of rubber-covered wire at specified test voltage. This test causes breakdowns at weak spots in the insulation which are cut out before shipment of wire in short coil lengths. Data obtained consist in records of the number of breakdowns in successive lengths of 10,000 ft. each. There may be 0, 1, 2, 3, ..., etc., breakdowns per length, depending on the number of weak spots in the insulation. Here there is no natural unit of product (such as 1 in., 1 ft., 10 ft., etc.), in respect to the quality characteristic "breakdown" since failures may occur at any point. Hence, n may be considered infinite and p infinitely small, although pn is finite. We may therefore forget p and n in the computations and use "number of breakdowns" as the statistic so long as we take *equal* lengths of wire. Figure 13 shows the control chart for pn.

TABLE X.—NUMBER OF BREAKDOWNS IN SUCCESSIVE LENGTHS OF 10,000 FT. EACH—RUBBER-COVERED WIRE.

LENGTH	NUMBER OF BREAKDOWNS	LENGTH	NUMBER OF BREAKDOWNS
No. 1	1	No. 16	20
No. 2	1	No. 17	1
No. 3	3	No. 18	6
No. 4	7	No. 19	12
No. 5	8	No. 20	4
No. 6	1	No. 21	5
No. 7	2	No. 22	1
No. 8	6	No. 23	8
No. 9	1	No. 24	7
No. 10	1	No. 25	9
No. 11	10	No. 26	2
No. 12	5	No. 27	3
No. 13	0	No. 28	14
No. 14	19	No. 29	6
No. 15	16	No. 30	8
Total		30	187

Central Line

$$\bar{pn} = \frac{187}{30} = 6.23.$$

Control Limits

$$\bar{pn} \pm 3\sqrt{\bar{pn}} = 6.23 \pm 3\sqrt{6.23},$$

0 and 13.7.

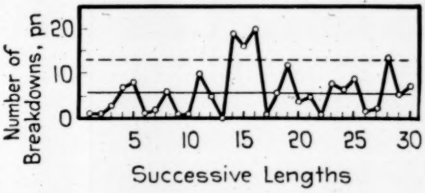

FIG. 13.—Control Chart for pn.

$\bar{p}$ and n indeterminate, no standard given.

RESULTS: Presence of assignable causes of variation is indicated by points falling above upper control limit.

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